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Computers in Dental Practice

Stephen Hill

Stephen Hill
30/7/97
– Just visiting Brisbane – enjoyed the Library!!

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To Rachel

Contents

Introduction

The purpose of this book is to review all the widespread uses to which computer technology has been, and is being, applied in dentistry. The main emphasis is on dental practice management systems, since this application has generated considerable interest within the profession over the last few years.

As little as ten years ago, most dentists would have dismissed as ridiculous the idea that one day they would use a computer to assist in the administration of their practice. But the development of the microchip has brought computing within everyone's reach, and the profession is responding enthusiastically to the challenge of the new technology. Some dentists have already installed computer systems in their practices, and the new proposals to link practices to the Dental Estimates Board (DEB) for electronic submission of NHS estimates will doubtless encourage the purchase of many more dental practice computer systems.

Yet the profession's experience of computers in dental practice has not been entirely happy. Many of the early practice management systems, developed at considerable expense by the 'pioneers' of dental computing, simply failed to live up to their promise, and this has resulted in bad publicity. If this has in turn caused dentists to adopt a more critical approach to the jargon and sales hype of the computer industry, then at least some good has resulted.

This book is aimed at today's general practitioner who – wisely – realises that computers have an important role to play in dental practice, and wishes to know more about them. We are currently on the threshold of a major advance in the scope of practice

automation, with the imminent computerisation of NHS estimates (discussed in this book). So far, the dentists buying computers have largely been those who are interested in them *per se,* perhaps having used home computers first. This book can be read by those who know little or nothing about computers, and I hope that it will appeal even to those who are not interested in computers at present – *because whether we like it or not, virtually all dentists will be using a computer in their practice before long.*

A useful analogy can be drawn between the current situation regarding the use of computers in small organisations (such as dental practices) and the situation that faced the early motorist at the beginning of this century. Cars were potentially useful devices, even in their early stages of evolution, but in order to derive any real benefit from a car, the motoring pioneer needed to be knowledgeable. The cars were, of course, very expensive; they were often difficult to start and to drive; and they were uncomfortable (the lack of windscreens and hoods made capes and goggles essential). Also, cars were unreliable, and there were not many garages around to provide maintenance or fuel. There were few signposts, few proper roads, and no motoring maps. There were no motoring organisations to provide advice or assistance. So, motoring was not the casual affair it is today: the early motorist was very much on his own.

Today's motorist, by contrast, has it easy. To begin with, cars come in enough shapes and sizes to satisfy most requirements. Everywhere in the developed world there are garages, filling stations, signposts, and good roads. So there really is no need to know much about cars to be able to choose the right one and use it effectively.

Within the next decade, the computer industry will be able to offer products that are as easy to use as today's cars. There will be cheap, reliable computer systems that can be easily tailored to the user's requirements. Until that time, dental practice automation will remain a minefield for the unwary or uninformed.

The applications of computers in dentistry will expand greatly over the next few years, and there will be potential for widespread benefits as well as undesirable results. In order to avoid the possible dangers and to achieve the benefits, dentists

should not rely solely on computer specialists. Instead, they should know a certain amount about computers so that they can help to prevent the design of ill-conceived computer systems. In other words, today's professional man or woman needs a modicum of *computer literacy.*

What, then, is 'computer literacy'? It has been defined as 'whatever a person needs to know and do with computers in order to function in an information-based society'. Functioning comfortably with computers is the key element; in other words, being able to use computers as problem-solving tools. So, how much do we need to know about computers to be computer-literate? After all, many suppliers of business and professional computer systems claim that their products can be operated by anyone – 'no knowledge of computers necessary, just insert the disk, switch on and follow the instructions on the screen'.

A balance needs to be struck. Obviously, one does not need to become an expert programmer to choose and use effectively a computer system in one's practice. But to buy computer software or hardware on the sole basis of advice from a supplier is to invite disappointment and unnecessary expense. Computer systems are highly complex and becoming ever more so. As members of a scientific profession, dentists should keep abreast of major technological advances affecting their lives. We do not rush out to buy new dental materials, for example, simply on the basis of claims by the manufacturers on behalf of the product; instead we assess them on the basis of published results of clinical trials, and on our own knowledge of dental materials science. Therefore, it is not unreasonable to expect that a dentist should have at least a basic grounding in computer science before purchasing a computer system for his or her practice.

Having thus established the need for every dentist to become acquainted with the fundamentals of computer science, the first major obstacle to be overcome is the widespread belief among newcomers to computing that the subject is so steeped in jargon as to be impenetrable. Indeed, the computer industry and its workers have long been accused of deliberately inventing and using obscure terminology for its own sake – for no better purpose than to give themselves a psychological advantage, by

making the uninitiated feel ignorant and vulnerable (this is of course a ploy of certain specialists in every discipline).

There is, sadly, some truth in this charge, as anyone who has ever bought a personal computer and tried to understand the manual will testify. Quite apart from the mysterious new words, such as 'byte', and seemingly endless combinations of letters and symbols (eg MS-DOS, Z80, CP/M, etc) computer literature is also liberally sprinkled with words and phrases which seem straightforward enough but turn out to represent quite unfamiliar concepts. For example, what should a dentist new to computing make of the term 'operating system'? Does it refer to a particular surgical technique?

We should not, however, be too eager to accuse the computer industry of coining new terminology with the deliberate intention of confusing the lay person. Any new technology or scientific discipline will inevitably develop its own new words and phrases and dentistry is no exception. But there are two main reasons why computer science has a particularly bad reputation in this regard. Partly, because the technology of computing has grown so much faster than any other, a large number of new words have had to be invented in a short space of time, too rapidly for them to have been readily assimilated into popular usage. But, more importantly, the pervasive influence of computers on every person's life has forced many people with no background or training in the use of computers to need to familiarise themselves with the new technology and its terminology. This has been a source of considerable difficulty.

The first chapter of this book therefore provides an overview of computer science. There is emphasis on describing the anatomy of a computer system and explaining the associated technical terms so that the newcomer to computers can appreciate the subsequent chapters. Those who already consider themselves 'computer buffs' can of course skip Chapter 1.

In order to assess whether computerisation of any particular activity within a dental practice is a desirable target, it is essential to understand the fundamental nature of the existing clerical activities, and this always turns out to be more complex than first thought. Chapter 2 describes how to carry out a thorough analysis

of the practice administration, which is a vital first step to be taken.

In Chapter 3, we consider what use can be made of computers in the dental practice, outlining the major administrative functions and giving arguments for and against computerisation of each one. In order to decide what sort of system is appropriate for a given practice, it is necessary to consider requirements in detail and this cannot be done properly without knowledge of what is practicable within the resources at our disposal.

The proposed scheme for the electronic submission of estimates to the DEB will, once successfully implemented, encourage many dentists to computerise their practice. Only in this way will they be able to take advantage of the benefits offered – a significant reduction in clerical work, more rapid processing of fee claims and requests for prior approval, etc. It is an important enough topic, therefore, to occupy the whole of Chapter 4. The scheme is described along with a review of the future direction of computing at the DEB, currently undergoing massive change.

Chapter 5 explains how to evaluate, select, purchase and install a practice computer system. The choice of the right system is becoming harder as more products appear on offer, and the computer industry has never been noted for the veracity of its advertisements. Therefore the practitioner needs to be able to spot defects in the systems he may be offered, and this chapter provides the necessary guidelines.

Topics relating to the security of computer systems are considered in Chapter 6. Here details are given of the Data Protection Act, and its implications for dental practice computing. Chapter 7 is concerned with some non-administrative uses of computers in the practice.

Finally Chapter 8 looks into the future – which in the world of computing is never far away. It seems likely that clinical applications of computers, such as to assist with diagnosis, or the interpretation of radiographs, will soon reach a sufficiently advanced stage of development for large-scale clinical use; this will doubtless change the way we currently think about computers in dentistry as primarily tools for business administration. When

this becomes a reality, the computer will be as essential a piece of dental equipment as is today's X-ray machine. No doubt by then (and this time may be as little as five years from now) much of the material in this book will be out of date. But the dentist who has made the effort to acquaint himself with the current status of computers in his profession will nevertheless have benefited; just as a knowledge of the past helps us to understand the present, so will a knowledge of the present help us understand the future. The next few years will certainly be exciting for those who can appreciate the benefits that computers will bestow on the dental profession.

1 Fundamentals of Computing

INTRODUCTION

Most people today have some idea of what a computer is. However, this book assumes no prior knowledge of the subject, so we must begin with a few not too rigid definitions. Let us start by defining a computer in terms of what it actually does.

It would be impossible to enumerate all the applications, or tasks, to which computers have been successfully applied. Even in the limited sphere of dentistry, computers are already being used for a wide variety of applications, the most important of which are covered in this book.

However, computers achieve this versatility in spite of having a very small number of functions – in other words they only use a few basic abilities in carrying out their tasks.

BASIC COMPUTER TASKS

Computer tasks can be broadly categorised as follows:

1 Calculation – for example, in working out treatment fees, wages, and practice accounts.

2 Storage of information – for example, a computer can be used to store lists of patients' names and addresses; in other words, as an 'electronic filing cabinet'.

3 Communication – computers can transfer information from place to place; for example, a computer terminal in a surgery can access information stored at reception, or even in a different building.

4 Control – computers supervise the sequence of operations in many items of modern surgery equipment; for example, automatic dental chairs are controlled by microprocessors.

In fact, any computer application, however complicated, can be broken down into some combination of calculating, storing information, communicating and controlling. This leads us to a definition of a computer:

> "A computer is a device that stores and manipulates data, that can control other devices as a result of its manipulation and storage of data, and that can communicate with other computers, with other types of device, and with human beings."

There is, however, something fundamentally anachronistic about the use of the word 'computer' with reference to most of the current and developing applications of data processing machines in dentistry, and indeed in general. The word implies computation, which in turn seems to be concerned primarily with manipulating figures and performing arithmetic calculations. In the early days of electronic computers, the 1940s and 1950s, this was an accurate reflection of the tasks for which these new machines had been developed; functions such as census counting, and payroll calculation for very large organisations. Computers are still used for these 'number-crunching' tasks, but they have become more than just powerful calculators. Their capabilities now extend over virtually all spheres of information processing, being capable of manipulating text and other symbols, as well as figures.

Because computers have become, in a short space of time, such a feature of everyday life, there is a tendency to regard them as a result of a fundamentally new approach to information processing. However, today's sophisticated electronic computers have a lot in common with much simpler calculating machines, and an appreciation of their historical development helps us to dispel much of the mystery surrounding them.

HISTORICAL BACKGROUND

The evolution of information processing began thousands of

rs ago. As social organisations such as tribes began to form, ords became necessary and so symbols were developed which eventually to standard alphabets. With the development of de and commerce, counting on fingers and toes led to the use stones and sticks as counters. This in turn led to the elopment of the familiar abacus which is still in use today in Orient, despite being over 2000 years old.

Manual record-keeping techniques continued to develop over centuries, with such innovations as record audits (invented by Ancient Greeks) and budgets and banking systems (invented he Ancient Romans). These new methods allowed trade and ustry to flourish, which resulted in an ever-increasing need for her record keeping and information processing. The first ulating machines appeared in the 17th century*; the most ortant of these was a mechanical calculator, invented in 1642 laise Pascal, a brilliant French mathematician. This invention onsidered so important in the history of computing that a ular computer language has been named after Pascal. Sadly, cal's machine was not a commercial success; it could do the k of six accountants, and people feared it would create mployment – a familiar situation today!

The first serious attempt to build an all-purpose computing chine was made by Charles Babbage (1792–1871), a professor mathematics at Cambridge University. Babbage was a some- at eccentric individual, who spent much of his working life igning a huge machine which he called the 'analytical engine'. was never satisfactorily built, due to lack of finance and the adequacy of then current engineering techniques, but many ople today believe that had it been built according to abbage's specifications, it would have become the first general- urpose computer, and a project is currently in progress at the ondon Science Museum to construct the machine in accordance ith the original specifications in order to find out whether or not will work.

The next major advance in information processing technology took place in the USA. The nation was undergoing extremely

*The Spanish theologian Ramon Lull, working in the 13th century, is said to have used a mechanical logic machine, though perhaps this does not qualify as a successful calculator.

rapid growth and development in the latter half of the 19th century, and the volume of business and government records was expanding at such a rate that reliance on the main tools – namely pencils, pens and paper – then available to assist information processing could no longer yield the required information in time for it to be of use. Information gathered in the 1880 census took so long to process that by the time the results were ready, it was time to begin the 1890 count. Fortunately, two innovations helped to improve the situation. The *typewriter* improved legibility and increased writing speeds. But even more important was the development of electromechanical *punched-card equipment.*

Punched-card processing is based on a simple idea. Information is recorded in a coded form by punching holes into standard-sized cards with a key-punch machine. The number and position of the holes determine the information encoded on each card, and each card represents a single record. In a census, for example, there would be a separate card punched for every person recorded, and the appropriate information relating to that person (such as name, date of birth, and address) would be encoded in the pattern of the holes on his or her card.

Interpretation of the information on a card is achieved by the detection of the presence or absence of holes in the card. Initially this was performed mechanically but later card readers used photoelectric cells. Once cards have been read, they can be counted and rearranged into a new order by further machines, known as *tabulators,* which summarise the required information and print reports.

The development of punched-card equipment made possible the development of information processing techniques which are still in use today. The technology was adopted by large organisations for large-scale processing activities and the punched-card equipment industry became well established during the first half of this century. As engineering and manufacturing methods improved, the tabulating machines became capable of processing cards faster and performing more complicated manipulations of the information contained on the cards.

It is interesting to note that most of today's major computer

mpanies originated in firms which manufactured mechanical nched-card equipment. The largest, IBM (International Busiss Machines Ltd) started with the 1911 merger of three of the rly punched-card equipment manufacturers. Today it is on rget to become the world's largest company before the end of e century. And the main British manufacturer of large mputers, ICL (International Computers Ltd) was formed in the e 1960s from ICT (International Computers and Tabulators) ich itself had been formed through a merger between the jor UK tabulating equipment manufacturers in the 1950s.

The information processed by tabulating equipment was cerned entirely with accounting and numerical calculations. ese calculations were performed on a basis similar to that nd in the abacus; columns of figures corresponding to units, s, hundreds and so on could be added or subtracted from each er according to requirements. Because each column was resented by figures on a revolving drum, and each drum olved on the same spindle, these machines could add two -digit numbers almost as quickly as they could add two gle-digit numbers (a small amount of extra time is taken to opagate the 'carry' digits); this gave them a great advantage er human beings, but they were no use for tasks involving ltiplication or division; try doing any calculation other than dition and subtraction on an abacus and you will appreciate y.

The mechanical and electromechanical tabulators were sucssful in their limited sphere. The punched-card technology volved sufficiently to allow reasonably fast and accurate capture d storage of information, and the adding and subtracting apabilities of the tabulating machines made them a viable roposition for many large-scale processing activities in the usiness and commercial world. But their lack of ability in erforming more complex arithmetical tasks rendered them entirely unsuitable for scientific use.

Impetus for the development of the first electronic computers developed in the Second World War. The first electronic general-purpose computer, the ENIAC (Electronic Numerical Integrated Calculator), was built at the University of Pennsylvania

in 1945, for the purpose of calculating bomb trajectories; this required the solution of complex simultaneous equations. Another important project for which powerful processing machines were needed was the breaking of enemy codes, and the first British computers were built for this purpose.

The new electronic machines had a similar principle of operation to that of their mechanical predecessors; they manipulated information stored in numeric form, and could only perform three basic operations on numbers thus stored (namely addition, subtraction, and comparison). However, there were two significant differences. Firstly, the new machines manipulated the stored information through electronic switching which, requiring no moving parts, was thousands of times faster than any mechanical device that could possibly be engineered.

The second major departure from previous data processing methods was the introduction of the stored program concept. A *program* is a sequence of instructions, possibly fixed, but possibly capable of being altered as a result of the outcome of earlier operations. Computers have the capacity to store programs inside themselves, within their *memory*. When the program is executed, each of the stored, coded instructions is fetched from memory, then decoded and translated into action, in the sequence determined by the program's structure.

The mechanical machines also did this to a limited extent. The punched-card sorting machines, for instance, embodied suitable instructions in their mechanisms which caused them to arrange each card in order according to the pattern of the holes punched in it. But this resulted in an inherent inflexibility: such a *dedicated* machine could not be adapted for general use. For more elaborate programs, the machine needs to be able to do more than simply carry out a fixed sequence of instructions; it needs also to be capable of altering its sequence of operations and even the nature of these operations, according to the result of an earlier operation.

(A visit to the London Science Museum is highly recommended to anyone who wishes to gain a perspective into how computer technology has developed. The exhibits in the Computers and Data Processing gallery include tabulators and early computers,

and illustrate clearly that development in computers has been evolutionary – although the evolution has taken place faster than in any other industry.)

The very first electronic computers were very costly and, despite their superior processing capabilities, seemed to pose little threat to the mechanical tabulating machines. The ENIAC weighed 30 tons, stood two stories high and covered 15,000 square feet, requiring a special building to house it at the University of Pennsylvania. It contained 18,000 valves, and used so much electric current that when it was turned on, all the lights in the city of Philadelphia dimmed. However, only a few years later, the invention of the transistor made possible the development of more compact machines, based on integrated circuits instead of on the bulky and failure-prone thermionic valves found in the first computers. By the early 1950s it was clear that the mechanical equipment had arrived at a development plateau; it did not have the development potential to compete with the new electronic machines which were then becoming commercially available. Even the ENIAC could perform 500 additions in one second, which was far more than the most advanced mechanical machine could achieve. By 1960 the computer had almost entirely superseded the mechanical tabulator, although mechanical desktop adding machines continued in popular use for another decade.

The second generation of electronic computers, which arrived in the late 1950s, were the first data processing machines capable of processing text in the form of letters and words, as well as numbers. These machines, being more powerful than their predecessors, were the first computers to be designed with non-scientific processing in mind. The major advance which made possible a vast range of text-oriented business and commercial applications was the development of the first high-level computer *programming languages*. Most people have heard of at least some of these – Basic, Cobol and Fortran are examples. These languages provide a syntax for expressing instructions to a computer; in order to produce a result, known in computer terminology as *output*, the computer requires a program, coded as a sequence of instructions, and information to be processed, known as *input*. Programs are generally referred to as *software*,

and the tangible components of a computer system, such as the computer itself and other peripheral items to which it is connected, are referred to as *hardware*.

The third generation of computer hardware arrived in the early 1960s. By this time, advances in electronics had led to the introduction of integrated circuits which in turn allowed more powerful processors to be built at lower cost. This led to the development of physically much smaller, yet more powerful computers which could reasonably be afforded by medium-sized firms and universities, although they still cost many thousands of pounds and were way beyond the reach of ordinary individuals. Because they were so much smaller than previous computers, and in accordance with the 1960s vogue for adding the prefix 'mini' to virtually anything that happened to be smaller than its predecessors, these machines were termed *minicomputers*.

There was of course still a need for very large computers, and these continued to undergo further development with the aim of increasing their processing capacity to cope with the greater demands made on them as firms computerised more and more of their functions. These came to be known as *mainframe* computers.

By the early 1970s, further improvements in the large-scale integration of electronic components made it possible to place a very large proportion of a computer's electronic circuitry on a small slice of silicon – the *microprocessor chip*. Early chips were used in electronic calculators and quartz watches which required relatively little processing capability. Once sufficiently powerful chips could be mass produced, however, it became feasible to use them as the central processor for a new type of small computer. Because these new computers were so much smaller even than the minicomputers, they were called *microcomputers*.

MICROCOMPUTERS

General

Since the advent of the first microcomputer, more than a decade ago, microprocessor technology has developed to the point where the latest microcomputers, built around advanced micro-

processors such as the Intel 80386, are more powerful than most mainframe computers of 20 years ago Yet some cost as little as £200 and prices will no doubt continue to fall. Of the present generation of microcomputers produced for business use, those based on the Intel 8086 processor are by far the most popular; these include the IBM PC and its many imitators. These cost under £1000 yet are powerful enough for many applications in dentistry.

Although this book will discuss one particular large mainframe computer system – namely, that of the Dental Estimates Board – the main area of interest will be microcomputer systems. These can be afforded easily by the dental practitioner, and yet are more than adequate for the requirements of a dental practice.

Having looked briefly at how microcomputers arrived on the scene, let us consider their fundamental principles of operation. By definition, a computer stores and handles information, controls, and communicates. The storage and manipulation of data are the two most important principles to understand.

Data

First, let us define the important word 'data'. It is not strictly correct to equate data with information; instead it is more accurate to say that data becomes information when it is communicated. Data is the plural* of datum, and a datum contains one discrete item of information, or in other words represents a single fact. For example, in an abacus the number of beads on each rung represents a single datum – in other words, the value of a particular digit in the number under consideration. So a six rung abacus which, assuming it worked in the decimal numbering system, would have ten beads on each rung, uses six data items, and in doing so can represent any number between 0 and 999999.

In the old mechanical calculating machines, each datum was represented by a wheel with the digits 0 to 9 which revolved to give the desired reading. However, a modern computer is a solid-state machine and has no moving parts within its processor,

* Though now regarded in computing as a singular noun.

only electrical pulses ebbing and flowing through complex circuits. How then can such a device represent data?

Instead of storing numbers and performing calculations in the decimal (or 'base 10') numbering system, computers work in the binary ('base 2') numbering system. The reason for this is that the binary system only uses the digits 0 and 1, which can be conveniently represented in electronic circuits as a current either being off or on. To represent numbers this way, more digits are needed, but this is no problem for a computer; it simply has an on/off switch to represent each digit. In the binary system, we 'carry 1' whenever the number 2 is reached in any column. So, whereas in the decimal numbering system we write 2048, meaning '2 thousands, 0 hundreds, 4 tens and 8 units', in binary this becomes:

2048	1024	512	256	128	64	32	16	8	4	2	1
1	0	0	0	0	0	0	0	0	0	0	0

or 100000000000. This may be confusing to the human reader, but is simple for the computer to represent. Any number up to 4095 (ie 111111111111 in binary) can be represented by 12 on/off switches. Each additional switch allows a number twice as big to be represented.

In a computer, the smallest unit of electronic storage is called a *bit*, which is an abbreviation of 'binary digit'. A bit is capable of positive or negative polarity, but no third state. The minimum number of bits we would need in order to be able to represent all the numbers from 0 to 9 would be 4, since 9 in base 10 equals 1001 in binary. If, additionally, we wish to represent all of the 26 letters from A to Z we would need 6 bits, since 36 in base 10 equals 100100 in binary

Even this is not enough, however, for, besides needing to represent lower and upper case letters and to be capable of distinguishing between them, we also need to deal with punctuation marks, spaces, and various other symbols if the computer is to be truly versatile and not a mere 'number cruncher'. Various systems have been devised for the purpose of coding all the letters, the numbers 0 to 9, and the important punctuation marks as sequences of binary digits. In microcomputers, the most commonly used coding system is ASCII, the American Standard

Code for Information Interchange. ASCII uses a seven-bit code, allowing 128 different characters to be represented. Computers however usually work with blocks of eight bits at a time, and the eighth bit is used as a checking device to help ensure accurate transmission of data from one part of a computer system to another.

A string of eight bits – which in its entirety can represent any one of 256 combinations of binary digits – is known as a *byte*, which is an abbreviation of 'by eight'. The *word length* of a given computer is the length of the string of bits with which it is designed to work. The first microcomputers were eight-bit machines; they had a word length of one byte and processed information in chunks one byte at a time. Most of the current generation of business microcomputers, including the IBM PC and its many competitors, can handle a 16-bit word, which means that they can process information much faster, and can also access a far greater memory space, as we will see when we consider storage in the next section. The newest generation of microcomputers, using the Intel 80386 and Motorola 68000 processors, can handle 32-bit words. These machines are so powerful that it will be some years before software is written that will enable their full processing power to be harnessed.

Processing

Besides data, the computer also needs to be able to represent and interpret instructions which tell the processor which actions are to be performed on the data. Consider the abacus again. Like the computer, an abacus stores data in numeric form. Imagine an abacus which worked in base 2. If it had eight rungs, it could handle information in the same way as an eight-bit computer, albeit at a much slower rate. So it could add and subtract numbers in the same way as the computer. But we know that computers can do much more than addition and subtraction. They can not only perform complex mathematical calculations, but can also process text. At this point the analogy between the abacus and the computer seems to break down.

As long ago as the 1930s, however, it had been realised that not only could all information be represented in numeric form by

using suitable coding methods, but also, more importantly, that any required processing of information thus encoded could be achieved by a machine capable of performing just three operations on the resulting numbers; namely, addition, subtraction, and comparison.

This theory was advanced by the great British mathematician Alan Turing (1912–54), who is now recognised as one of the most important contributors to computer theory. Although at the time of publication of this theory no electronic computers had been built, Turing realised that the construction of machines capable of performing simple operations on binary numbers at higher speeds would allow more complex processing of data.

In a computer, each instruction which tells the processor which operations to perform on data is made up of some combination of the three basic operations, addition, subtraction, and comparison The other main types of instruction needed are input/output instructions, necessary to permit communication between the processor and the outside world, and storage and retrieval instructions which move data between the processor and the various storage devices during processing. Each different type of processor has its own set of instructions, and these are assigned binary codes to allow the processor to distinguish between them. So, both data and instructions are presented to the processor as a sequence of binary digits.

In order that a computer system can process data rapidly, it needs to be able to access and transfer items at very high speeds. *Memory* is the term given to that part of the computer hardware in which data or instructions may be stored. The larger the memory space within the computer, the greater will be the amount of data, and the larger the instruction sequence, that can be stored within it. Therefore, a computer system should ideally have unlimited memory space, from which data in all locations can be accessed instantly. However it is an unfortunate fact of life that the fastest memory has the highest cost.

So all computer systems, large or small, have a hierarchy of memory types providing a compromise between storage requirements, speed of access, and financial constraints.

Memory

The main memory of a microcomputer can be regarded as a sequence of contiguous memory locations, each of which has a unique address in order that it can be distinguished from other locations. Each location can hold one byte, which may represent either a data item or an instruction to be carried out by the processor. This main memory is called random access memory (RAM), because the time taken to access any location is always the same. RAM is volatile; in other words, the contents of any location can be written, read, and erased while the computer is switched on, and all the contents are lost when the computer is switched off. Most computers also have a certain amount of read only memory (ROM), which is non-volatile and can only be read, not written to. ROM is used to hold the information the computer needs to get itself running every time it is switched on; this information never needs to be changed.

At this point, a further distinction must be made between instructions and data. As we saw earlier, a program is a sequence of instructions that performs a particular task. When we load, say, a recall-list program into a computer it will cause a prompt to be given to supply it with some names and addresses to process. These names and addresses constitute the data on which the recall-list program will perform the required operations, such as sorting by name or by date of last appointment. Although both program and data are nothing more than sequences of zeroes and ones, and these may well be intermingled in the computer, with a machine instruction and a data item occupying adjacent locations in RAM, we must nevertheless maintain a conceptual distinction between them.

The amount of RAM in a computer determines the upper limit to the complexity of applications it can deal with. The smallest unit of RAM is a byte, but for practical purposes, most people think in terms of kilobytes (KB) and megabytes (MB). A kilobyte is, confusingly, not 1000 bytes as would be expected, but 2 to the power of 10, or 1024 bytes; a megabyte equals 1024 kilobytes, or 1,048,576 bytes – just over a million. To give some idea of how these units relate to programs and data, in terms of text storage a page of A4 typing occupies about 2 KB. The limit to the

complexity of programs that will fit into a given RAM space is more difficult to define, since the greater the skill of the programmer, the better use can be made of the available memory, by use of the most appropriate machine instructions, written in the most suitable programming language. The early microcomputers had tiny amounts of RAM by today's standards, yet ingenious programmers still managed to get their programs to fit. Quite respectable chess playing programs, for example, were written to run on the first British 'home computer', the Sinclair ZX80, which had only 1 KB of RAM. Obviously, given such severe constraints, most of the memory locations are taken up by processing instructions, leaving little room for storing text to give on-screen instructions to the user, or for storing graphic representations of the chess pieces. Today's microcomputers usually have at least 128 KB of RAM, and business micros have upwards of 512 KB. A RAM of this size can store complex sequences of operations and have room left for instructions, prompts, comments, and the so-called 'bells and whistles' – sounds or screen messages that help the user to understand what is going on.

While the amount of RAM in a computer exerts a strong influence on the maximum size of programs that it can execute, this figure tells us nothing about the speed with which it can execute them. Speed is governed mainly by the type of processor used – the 16-bit processors are faster than 8-bit machines since more bits are handled at a time. But an additional important factor is the *clock speed* of the particular machine which can vary widely. The standard IBM PC, for example, uses an Intel 8088 processor chip running at a clock speed of 4.77 MHz – this means that the chip uses signals at a frequency of 4.77 million cycles per second to control its basic internal operations of addition, subtraction and comparison. The Amstrad PC, one of the many cheap imitators (or 'clones') of the IBM PC, uses a larger version of the same chip, the 8086, but improved hardware design gives it a clock speed of 8 MHz. Put simply, this means that it will run the same programs as the IBM PC, but nearly twice as fast. Some of the new 80386 systems run at 16 or even 20 MHz.

We defined computer hardware earlier as the physical components of the computer system, and software has been defined as the invisible components, namely the instructions that are

presented to the computer system, which cause it to process input data, producing a result, or *output*. However, software is a rather anachronistic term, since with the advent of ROM chips containing programs which can be simply plugged into some computers, the distinction between software and hardware has become blurred.

PROGRAMMING LANGUAGES

We have seen how data and instructions are represented and stored in a computer system. Since instructions are built up from the three fundamental operations, to write programs using only individual machine instructions would be an enormously laborious task. In order to provide a compact, powerful notation for specifying instructions to a computer processor, various *programming languages* have been developed. A language is simply a means of communication. In computer terms, a programming language accepts certain types of instructions that will enable a computer system to perform a number of familiar operations.

Computers existed before programming languages, and it is important to appreciate that instructions written in a high-level language such as Basic or Cobol cannot directly be understood by the processor which, as we have seen, can only interpret zeroes and ones. There are recognised 'generations' in software evolution, as with hardware. The first generation of software was written entirely in *machine language* – in the zeroes and ones used by the processor. Both instructions and data had to be presented in this form. An instruction prepared in any machine language has at least two parts. The first part is the command, or operation; this tells the computer what function to perform. Every computer has a specific operation code (or 'op-code') for each of the different operations it performs. The second part of the instruction is called the operand: this tells the computer where to find or store the data or other instructions which are to be processed.

By today's standards, programming the first generation of computers was a very laborious task. Since both instructions and data had to be presented in binary form, a programmer had not only to remember the dozens of code numbers for the commands

in the machine's instruction set, but also was forced to keep track of the storage locations in the computer's memory of data and instructions. An early improvement was the development of *assembly languages,* in which mnemonic operation codes were substituted for the numeric machine language op-codes. For example, in assembly language one might write ADD instead of a sequence of eight or more binary digits, to tell the processor to add the next number to one already stored.

Machine code and assembly languages are referred to as low-level languages because they are machine oriented – they are used to express instructions in a way far easier for the machine to understand than for humans. High-level languages, on the other hand, are far more like written English and can be understood more easily by humans. A program written in a high-level language must be translated into machine language by a translating program before it can be understood by the machine. These translating programs are of two types. The most common are called compilers. A compiler takes an entire program written in a high-level language (the source program), and translates it into machine language (the object code). Alternatively an interpreter may be used. An interpreter translates source code one line at a time and executes the instructions in that line before proceeding to translate the next line. The advantage of interpreters is that they make for easier program development, since it is not necessary to retranslate the entire source program to remove a single error as with compiled programs. However, compiled object code has the advantage of running about ten times as fast as interpreted source code.

A major advantage of high-level languages is that they are designed to be portable – a program written in a high-level language should be able to be transferred from one type of computer to another with little or no modification, whereas low-level language programs can only be run on the specific processor for which they were written.

The high-level languages are sometimes referred to as third-generation languages. Although many have been developed, the only three that find any significant use in dental practice computer systems are Basic, Pascal, and Cobol. Basic (Beginners All-

purpose Symbolic Instruction Code) was designed in 1964 as a simple yet powerful programming language for beginners. It has become so popular that there is virtually no microcomputer system which is not supplied with a version of Basic. However, although a standard Basic exists, it is not universally accepted – all software companies extend the language to suit their own requirements, and many different dialects exist. Unfortunately, the early versions of Basic, being designed for small computers with little available memory, did not have many of the features of more powerful languages, and this resulted in the language being looked down on and derided as a 'toy' language. Although these criticisms were certainly justified at the time, most of the newer Basic dialects have ironed out these problems, and, while they are still not sufficiently structured for very large commercial applications, there is no reason at all why simple but effective dental practice management software cannot be written in Basic by a practitioner for his own use; although professional programmers will probably use a more advanced programming language.

Some dental practice management software is written in Basic, then translated into machine language using a compiler. This means that programs can be developed relatively easily; yet compilation into object code makes them still run acceptably fast.

The chief disadvantage of Basic as regards building more complex computer systems is that large Basic programs tend to become very unwieldy and unstructured. Unfortunately, the 'user-friendliness' of Basic is something of a two-edged sword; while it allows novices to get useful programs running quickly, its flexibility and simplicity results in a lack of discipline on the programmer. This inevitably leads to 'short cuts' in programming, and this is no recipe for a successful large system, since the resulting programs are very difficult to maintain: the important subject of software maintenance is dealt with in Chapter 5.

The language Pascal, named after Blaise Pascal, was introduced in 1971 with the intention of providing a more structured alternative to Basic for small systems development. Although it has traditionally been the programming language taught in academic institutions, finding little acceptance in the commercial field, the recent introduction of highly efficient and easy-to-use

Pascal compilers, such as Turbo-Pascal written for the IBM PC, has resulted in an increased use of the language by commercial software developers. Although Pascal is a more difficult language to learn and use than Basic, programs written in Pascal run much faster and are far easier to maintain.

The classic programming language for large commercial systems development is Cobol (Common Business Oriented Language). There are many criticisms of Cobol; it is difficult to learn, extremely verbose and tedious to write, and many of the concepts behind it are far more attuned to the requirements and attitudes of the 1950s than the 1980s. Yet it survives and is by far the most popular commercial language because it has always had the benefit of being standardised. The standard is determined by a committee which meets every ten years or so to review the language and add new features which are agreed to be desirable. The original Cobol standard was published in 1959 and the most recent revisions were made in 1985. Because Cobol is such a complex language, with many features not found in simple languages like Basic, it was not possible to implement it on early microcomputer systems. It is now widely available for business microcomputers however, and is a suitable language for developing a comprehensive dental practice management system.

The present high-level languages have evolved sufficiently to allow efficient expression of instructions to a computer. However, this still requires a considerable amount of programming skill. The ideal situation, as seen in science fiction films, would be if humans could use natural language to communicate with the computer. This would allow anyone to indicate what information was required by using spoken or written words to communicate this to the computer, thus obviating the need for programmers. Unfortunately this utopian notion is still a long way off. However, there have been many important developments in natural-language processing and this will have an impact on dental computer systems in the next decade.

At this point a brief mention should be made of another language, Prolog. At the time of writing, its use in dental computing is almost non-existent. Yet it has been chosen as the language around which the so-called 'fifth-generation' of computers will be based. We discuss this further in the final chapter when future developments are considered. However, the reader should be aware that the next decade will see the emergence of increasingly intelligent computer systems able to assist in all types of clinical decision making (for example, in diagnosis). These intelligent applications require a fundamentally different approach to programming, which uses *declarative* languages – in which knowledge is built into the program in the form of rules, rather than the programs simply comprising sequences of instructions. Prolog is a prime example of a declarative language.

OPERATING SYSTEMS

When buying a computer program to run a specific application in a dental practice, or in any other environment for that matter, the dentist does not need to concern himself with the language in which the program was written. Indeed it will not be possible in most cases to determine the source language, as most commercial programs come ready compiled into object code. What is important, however, is the *operating system* under which the program is designed to run. An operating system (OS) is an integrated set (or 'suite') of programs, which is used to manage the resources and overall operations of a computer system. The purpose of an OS is to isolate the hardware from the user, so that he need not be concerned with the 'nuts and bolts' of the computer; instead the user communicates with the OS, which in turn governs the internal operations of the hardware. Functions performed by the OS include detecting which of the keys on a keyboard have been pressed, controlling input from storage devices and the keyboard, and controlling output to the screen and other devices.

The main importance from the user's viewpoint is that programs written for a particular OS will run on all computers which use that particular OS. So, while there are literally dozens of different makes of computer using the Intel 8086 processor, when buying an applications program the owner of any such machine need only concern himself with what OS the program was designed to run under, not whether the program was written specifically for his machine.

The first popular OS for microcomputers appeared in the late 1970s. Called CP/M (Control Program for Microcomputers), it was designed to be run on 8-bit machines. However, the advent of the IBM Personal Computer (PC) in 1981 set a new standard for 16-bit machines. The IBM PC family and their many imitators use an OS called MS-DOS (Microsoft Disk Operating System). Over the last five years, MS-DOS has undergone many refinements to enable it to manage improved versions of the IBM PC's hardware. Although IBM announced a new family of microcomputers, called PS/2 (Personal System 2) in 1987, with a new operating system, OS/2, the new machines will also run MS-DOS, and it is certain that the MS-DOS standard will be around and flourishing for a long time to come.

UNIX is another operating system which is finding increasing acceptance. This system was developed nearly twenty years ago, by Bell Laboratories, the research division of AT&T, the American telephone company which has been responsible for many important developments in computer hardware and software. Unlike MS-DOS, UNIX is designed to support timesharing – a means of sharing the resources of a central processor among a number of concurrent users.

So far we have considered in some detail how data and instructions are represented in a computer system, and how the system interprets and executes the instructions to perform the required operations on data. We will now consider the other components of the computer system, often referred to as peripherals since they need not be physically enclosed within the computer unit. These can be broadly categorised into input, output, and storage devices. The term 'peripheral' seems to suggest that these devices are somehow less important than the actual 'guts' of the computer, ie the processor and its associated RAM, but this is far from the truth. The most powerful processor on earth, with an infinite amount of RAM, is of no practical use whatsoever without devices which allow instructions and data to be input to it and output from it.

INPUT DEVICES

The original computer input devices were of course punched-card

readers; these are now obsolete. The commonest method of entering data or instructions into a computer system is via a standard typewriter *keyboard*; the keys, when depressed, move switches which cause a succession of electronic pulses to be sent to the computer; these pulses are interpreted as zeroes and ones using the familiar ASCII code. The keyboard is often cited as the chief obstacle that newcomers to computing have in getting familiar with the use of the machine. Indeed, learning to type quickly and accurately is not a trivial task. It is not widely appreciated that the standard QWERTY keyboard layout was in fact designed to be difficult to use, or 'user-hostile' in today's terminology. The primitive mechanisms of early typewriters would jam when keys were depressed in too rapid succession; the keys were therefore deliberately positioned in such a way as to impede rapid typing. Despite many attempts to introduce more rational keyboard layouts, the QWERTY standard has persisted; universal acceptance being its only virtue.

Another input device becoming rapidly more popular is the *mouse*. It is a small box-like object which fits snugly in the palm of the hand, and has a tracker ball inserted into its base. It is moved by the user across the desktop, and as it is moved, rotations of the ball cause electronic pulses to be transmitted to the computer either via a connecting cable or by a remote infra red control mechanism. These signals are interpreted by the processor and cause movements of a pointer or cursor on the screen. The mouse is usually used in conjunction with WIMPS software (ie programs which use Windows, Icons, Mice and Pointers). This is a generic term for a user-friendly style of interaction between the computer and the user. Windows are different sections of the screen in which information can be displayed.

This is usually in the form of menus (lists of possible actions to be chosen by the user) or icons (stylised pictures representing the different objects that can be manipulated by the various program actions). The pointer can be moved to a certain item on a menu, or to a certain icon, then a button on the mouse can be pressed to initiate the function or action represented by the item selected.

So the mouse is more suitable for choosing desired instructions to be input than for actually inputting data, such as names and

addresses, to the computer. The advantage of WIMPS programs is that they allow the mouse to be used in preference to the keyboard for much, but not all of the time.

At the present time, the keyboard and the mouse are the main input devices available for use in a dental practice, though the future will bring many improvements, the most important of which will be voice input. This and other developments will be discussed in the final chapter.

OUTPUT DEVICES

The two most important output devices are of course the visual display unit (VDU) and the printer. The VDU is simply a high resolution television screen, and can be monochrome or colour. Nowadays there tends to be little difference between the prices of monochrome and colour units. Colour screens are capable of presenting more information at a given instant, since the use of different colours on the screen can act as a 'key'. However, monochrome units tend to have higher resolution and cause less eye strain when operated over long periods. In a dental practice, monochrome displays are perfectly adequate for administrative applications, but colour displays may be desirable for patient education programs and also some of the more exotic applications of the future such as the diagnosis of various pathologies, and radiographic interpretation.

Early microcomputer VDUs could only display letters and numbers and this was a severe limitation. Indeed, some could only display upper case letters and numbers. A modern VDU should be able to display upper- and lower-case letters, and all numbers and punctuation. It should also have some capacity for displaying high-resolution graphics on the screen, otherwise it will be incompatible with WIMPS-based software, and will be unable to display dental charting, or business graphics for accounting purposes, nor indeed will you be able to use it to play games on!

The majority of business computers are supplied with a suitable VDU, but in some cases, the VDU has to be purchased separately. The temptation to reduce cost by using a domestic television set instead of a VDU should be firmly resisted. The

resolution of a TV receiver is simply not adequate for displaying text output from a computer, and attempts to use it for this purpose will rapidly result in severe eye strain!

The VDU is the medium of choice for displaying an instant answer to an enquiry, for example to confirm or check an appointment, and it also provides useful feedback, allowing the user to see what has just been typed on the keyboard. However, in order that the computer should be of use in a business environment, some means of producing hard copy is necessary. This is achieved through another output device, the printer. These come in several very different types. The most popular type of computer printer is the *dot matrix*, so called because characters are formed by dots of ink deposited onto paper by the selective impact of a number of plastic or metal spokes, from an array of available spokes. Dot matrix printers have been criticised for their relatively poor print quality, since the characters produced are discontinuous and tend to be less visually acceptable than the continuously drawn characters produced by other printing techniques. However this problem has been alleviated in newer models by having more pins in the matrix, thus producing more dense characters.

The other disadvantage of dot matrix printers is their high noise level during printing. Again this is less of a problem with more modern machines; but the advantages of dot matrix printers are considerable. Firstly, they are fast, usually managing at least 200 characters per second, and they are inexpensive; prices start as low as £200. The other major advantage is their versatility; because the print is made up of dots, graphics can be printed as well as text. Also, different sizes and different fonts of characters can be produced easily by means of appropriate software which configures the dots in the required arrangement.

The other traditionally popular type of printer is the daisy wheel. This is a similar device to the 'golfball' found in some electric typewriters; it contains a circular plastic disk, on which are embossed its characters. Disks can be changed at will to give different typefaces or print sizes. Control signals from the computer cause the wheel to be rotated until the appropriate character is in position, then it is impacted against the paper.

Daisy wheel printers tend to be less noisy than dot matrix printers, and give true letter quality print, but are much slower, typically achieving a speed of about 30 characters per second. Prices are usually more expensive than for the dot matrix printers.

A recent development has been the introduction of relatively low cost laser printers. These are high-quality, quiet, non-impact printers which use a photosensitive drum, similar to that used in photocopiers. An image pattern is written on the drum, using a computer controlled laser light beam, which scans across the drum by the use of rotating mirrors or photographic plates that can bend the beam, and is turned on and off as required by the computer. Ink particles are then brushed onto the laser-charged parts of the drum surface, and these in turn are transferred to sheets of paper onto which they are fused by heat, pressure, or a combination of the two. Prices range upwards from about £1500 and it is unlikely that these machines will compete with the more established technologies in terms of price for a long time to come. However they are much faster than the other types of printer; their speed is not measured in terms of characters per second since they print a page at a time. Even the most inexpensive laser printers can produce about ten pages per minute, and graphics and typeface changes can readily be achieved.

Movement of the paper through dot matrix and daisy wheel printers can either be by friction against a typewriter-style platen, or by revolving sprockets which engage in holes punched at regular intervals in either edge of continuous feed stationery. Most printers have attachments which allow either method to be used. Friction feed is useful for printing onto quality stationery, perhaps with a practice logo or address preprinted, but sprocket feeding with continuous stationery allows far more accurate alignment, which is essential for printing onto forms, or for printing letters for use in window envelopes. Laser printers, like photocopiers, have elaborate paper feed mechanisms; usually the printer tray is loaded with a supply of sheets, and feeding takes place automatically.

STORAGE DEVICES

As we saw earlier, the computer has a certain amount of memory

actually contained within it; namely the RAM, which is volatile, and the ROM, which is permanent, but can only be read and not written to. Together these comprise the computer's primary storage. Obviously we need non-volatile media for storing both programs and data, and a variety of such secondary storage devices are available. The original secondary storage medium was the punched-card; for many years this was the standard means of storing coded information. Current storage methods, however, instead of recording data by means of the presence or absence of holes in consecutive positions on pieces of cardboard, record data by means of the presence or absence of magnetic charges at consecutive positions on magnetic disks or tapes.

Anyone familiar with the early 'home computers' of a few years ago will recall that they used ordinary cassette tape for storing programs on. This had two big advantages; firstly, since virtually everybody already owned a cassette tape recorder, no additional equipment needed to be purchased, and even more importantly, cassette storage was (and still is) very cheap. A blank one-hour tape, costing less than £1, can store several megabytes, and, since most home computers had 64K of RAM or less, this meant that a single tape could store dozens of programs of the maximum size that these machines could cope with. However, tape storage had two important disadvantages. The most obvious was that transfer of data and programs to and from tape is slow, typically taking place at a rate of about 10 KB per minute. The rate of transfer is governed by the speed of the tape and the density of bits (stored as positive or negative charges) that it is capable of recording. While a data transfer rate of 10 KB per minute might be acceptable in a home computer where the largest program might only occupy 30 or 40 KB, it is clearly not acceptable in a modern business computer which might need to deal with 500 KB or more of data and program instructions at any given time; a practice computer which took an hour to load up its programs and data would not be much use!

The other, even more serious disadvantage of tape storage is that it will only allow sequential access to data or programs stored on it. To help in understanding the consequences of this limitation, imagine you are playing your favourite music album. You have bought the LP version of the album, and have made a

cassette tape copy (illegal, but you want to listen to it in your car). Having played the first track on one side of the tape, you wish to proceed directly to the 6th track on the same side. But the only way you can get there is by going through tracks 2,3,4 and 5. Admittedly you can use the fast forward facility. But this still takes time. Using your LP, however, you can move from track 1 to track 6 (or any other track you choose) as quickly as you are able to move the arm across to the chosen track, without going through the intermediate tracks.

The LP therefore can be said to allow direct access to any chosen track. This is the type of access we want in a computer system, so the most popular type of secondary storage, namely magnetic disk storage, works on a very similar principle.

All magnetic disks are round platters coated with a magnetis able recording medium. Information is stored on them as individual bits, represented by very small areas of magnetic polarity; the polarity of each area determines whether a one or a zero is stored there. However, their similarities end there. Different types of disk come in different sizes, and can be either removable or permanently fixed in their storage devices (called disk drives). And they can be made of rigid metal or flexible plastic.

The two main types of magnetic disk are 'floppy' and 'hard' disks. Floppy disks were first developed in the early 1970s. They are flexible plastic disks, individually packaged in protective envelopes. The early floppy disks were eight inches in diameter, but these have been superseded by the current 5.25-inch standard. A newer development has been the 3-inch disk, which is enclosed in a rigid plastic covering and is not 'floppy' at all, yet the technology is similar. The amount of information that can be stored on a floppy disk varies, as some disks allow writing to both sides, and double and quadruple density disks are available. The average capacity of a floppy disk is between 360 KB and about 1 MB.

Floppy disks have several important advantages. Firstly, they are cheap. A box of ten good quality blank 5.25-inch disks costs about £8–£10. Secondly, they are transportable and can be sent through the post. Therefore they are an ideal method of

distributing software, and virtually all commercial software for microcomputer systems is supplied on floppy disks nowadays. However, they are fragile and must be treated with care.

There are several different types of hard disk, but by far the most important in today's microcomputer systems is the Winchester disk. These are rigid disks permanently housed in sealed units which incorporate the disk drive. They have a much greater capacity than floppy disks; an average capacity is 20 or 30 MB, though 80 and 100 MB capacity Winchesters are now available. Furthermore, the time taken to access data from a Winchester disk is ten times faster than for floppy disks. Until recently, Winchester disks were very expensive and had a poor reputation for reliability, but nowadays most serious business microcomputers come with a Winchester as standard.

We can now consider how data is stored on and read from both floppy and hard disks, and contrast the two types. Earlier on, magnetic disks were likened to LP records with regard to their direct access capabilities. On an LP, music is stored in a continuous groove that spirals into the centre of the record. But there are no grooves on a magnetic disk. Instead, data is stored on disks in a number of invisible concentric circles, called tracks. Tracks are numbered consecutively, beginning from the outer edge of the disk.

During either a reading of data on the disk or a writing of data to the disk, a motor in the disk drive rotates the disk at a constant and rapid speed. In the case of floppy disks this speed is 300–400 revolutions per minute (rpm), whereas hard disks are rotated at 3000 -4000 rpm. Data is recorded on the disks as a sequence of tiny magnetised areas on a track. The direction, or polarity, of the magnetism at a given spot determines whether it represents a zero or a one. This data is read from or written to the disk by one or more read/write heads. The writing of new data to a track will erase whatever data was previously there, as in an audio tape system. In floppy disk systems, the head is actually in contact with the disk; inevitably this causes a degree of wear in the magnetic coating on the disk, consequently floppy disks have a limited life and cannot be used indefinitely.

In the case of hard disks, the heads do not actually come into contact with the disk surface, but instead 'float' on a cushion of air a few millionths of an inch above the surface of the disk. The high data density of modern hard disks has been achieved through reducing the flying height of the read/write heads over disk surfaces. Each reduction in height allows an increase in bits stored per inch of track, and in the number of tracks per inch on the disk surface However, since the read/write heads fly over the disk surface at a speed of over 100 miles per hour and a height of less than 20 millionths of an inch, clearly the environment must be controlled to keep out any dust particles or debris; hence the requirement for these disks to remain in sealed units.

To appreciate the engineering tolerances embodied in Winchester disk technology, consider that the speed of rotation of the heads, and the clearance between heads and disk, are comparable to an aircraft flying at 600 mph around the circumference of a lake, at an altitude of ¼ inch. So it is hardly surprising that Winchester disks sometimes develop faults. The most serious Winchester fault is the so-called head crash. If a particle of dust or debris somehow finds its way into the path of the flying head, the resulting collision can cause the head to bounce upwards, then crash on the far side of the offending particle. Such a crash will usually damage the head and the disk, and will corrupt the data stored on the disk.

Fortunately, as technology improves, hard disks are becoming more reliable. Yet, since a hard disk can hold so much data, the results of a head crash can be truly catastrophic. Therefore it is important not to be beguiled by the hard disk's convenience and speed of data storage and transfer. Always treat them with suspicion; in practice this means keeping a copy, or backup, of all vital data stored on a hard disk. Backups should be taken at regular intervals if the data is constantly changing, so that only the most recent data will be lost in the event of a hard-disk failure.

This raises the question of which storage medium should be used for making the backup copies. If the data within a system does not change very much from one day to the next (for example, in a patient recall system where, say, 20 names are

added to the recall list each day and a further 20 are removed) floppy disks can be used. Since floppy disks can become damaged quite easily it is wise to keep two backup copies. However, if most of the hard disk space is taken up by data which changes frequently, as opposed to programs, which tend not to change, backing up using floppy disks becomes very tedious. Assuming that a floppy disk can hold 360 KB of data, an average amount, in order to back up a single copy of a 20 MB hard disk you will need about 60 floppy disks, and the process would take well over an hour; to do this on a daily basis would clearly be unacceptable. The storage method of choice for backing up large amounts of data from a hard disk is the tape streamer; this uses magnetic tape, often in cassette form, but reads and writes data at very high speeds; a 20 MB Winchester can usually be backed up in about four minutes using a tape streamer. A tape streamer will only be necessary in a large practice with a number of terminals; for a smaller system, backup using floppy disks will probably not be too tedious.

2 Analysis of Practice Administration

GENERAL

A recent survey of 1000 randomly selected general dental practitioners revealed that 33% felt that the time had arrived for computerisation of at least some aspects of their practice. However, the general dental practitioner is a businessman: he has to work hard for his money, and likes to be sure that he is getting good value for it. There is considerable evidence that dentists set an upper limit each year to their capital expenditure on practice equipment. Therefore if a computer is to be purchased, it is likely to be at the expense of some other major item. Hence the importance of being fully aware of what benefits a computer can bestow, in order that these benefits can be weighed up against those that would result from some other major purchase, such as a new X-ray machine or dental unit.

It is worth considering first what the overall goal is in a dental practice, before we consider the more tangible subgoals to which computers may be applied. Broadly speaking, the prime goal of the general dental practitioner is to provide the best patient care possible. The second major goal is that common to all businesses, namely to make a profit.

There is every indication that within the next ten years there will be widespread availability of computer systems that will directly assist the dentist in providing better patient care, and computers will then be regarded as an essential part of our clinical equipment. Such systems might assist us in clinical decision making, suggesting appropriate treatment plans, providing accurate diagnosis of radiographs, and in many other ways. However,

such developments are not yet with us. *Current* computer systems are capable of helping us to achieve the second goal, that of profitability. Of course, in doing so, they can indirectly help the dentist to provide better patient care, since they can free him from many mundane administrative tasks, leaving him with more time to perform critical dental duties.

TASKS

Anyone who has worked in a dental practice will be aware of the large amount of clerical work involved in such an organisation. As well as the correspondence, invoices, accounts, wages, and other matters involved in running any business enterprise, there is also a vast amount of information specifically relating to the dental treatment that is provided. Each clerical process can be regarded as a function of the practice, a task that must be performed for the whole practice to run smoothly. It is immediately obvious that a large number of such functions exist within a practice. To illustrate this, consider all the clerical activities resulting when a patient attends a practice for the first time. We will assume the information flow and data processing requirements of a mainly NHS dental practice, with particular reference to the actual forms and documents required by the National Health Service since over 90% of dental practitioners in the United Kingdom treat some or all of their patients under the terms of the NHS, and the vast majority of dental treatment is still carried out under this scheme.

When a patient attends a dental practice for the first time, he or she needs to be registered. The patient's details – including name, address, date of birth, and telephone number – are written on a patient record card (FP25). Any treatment carried out at that visit, or at subsequent visits, must be noted on this card. Before being examined, the patient must sign an estimate form (FP17) which the dentist will submit later to the Dental Estimates Board to claim remuneration or to request prior approval. Assuming that an examination is done at the first visit, details of charting have to be noted on the reverse of the FP25. If the patient requires further appointments, these have to be written in an appointment book, after the book has been searched to find a suitable space. Then an appointment card has to be written out.

If X-rays have been taken, or any chargeable treatment performed, and the patient is not exempt from charges, the amount chargeable needs to be calculated and a receipt given to the patient to acknowledge payment. Also if further treatment is planned, a full estimate of the patient's charge should be given; this requires further calculation. When a course of treatment has been completed, the FP17 estimate form must be completed and posted off to the DEB. Usually the patient's name will then be put on a recall list, so that he can be sent a reminder to make another appointment after the appropriate time interval.

The above overview of the paper processing relating to a single course of treatment of a given patient leaves out much of the detail, but it serves to indicate a minimum level of clerical work that is necessary even in the most straightforward and uncomplicated case. The clerical functions described are all time consuming, but some are more of a problem than others, and the priority given to computerising a given clerical function will vary between practices.

SYSTEMS ANALYSIS

It must be stressed that computerisation will not by itself turn an inefficient practice into an efficient one. Indeed, if an inherently unsatisfactory manual system is computerised, the outcome may well be that efficiency is reduced even further. Before considering the purchase of a practice management computer system, therefore, the dentist must undertake a complete analysis of the practice, identifying every function and activity within it. This process is known as *systems analysis*.

The importance of systems analysis cannot be too highly stressed. This process can be likened to the treatment-planning phase in clinical dentistry. A rigorous analysis can help the dentist to gain an insight into the way his practice runs; and this usually turns out to be far more complex than first thought.

A *system* is defined as 'a network of interrelated functions or procedures joined together to form an activity'.

A *procedure* is defined as a series of instructions that explain:

— What is to be done

— Who will do it

— When it will be done

— How it will be done

Every organisation can benefit from a thorough analysis, even if the management currently have no intention of computerising. Indeed, even before computers existed, a well defined area of expertise concerned with organisation and method (O&M) analysis had developed. O&M analysts were employed by large organisations to perform a thorough, detailed analysis of all the activities of the organisation, assessing which areas could benefit from changes in working practices. The investigation and assessment techniques of systems analysis have evolved from those used in O&M analysis.

It may not be immediately obvious why a small business such as a dental practice needs to concern itself with such techniques. After all, the vast majority of dentists work in small practices of up to three practitioners. They do not as a rule employ large numbers of staff, and the management functions, while time consuming, seem straightforward. The complexities inherent in the administration of a business tend to become more apparent when new members of staff are hired, particularly if they are inexperienced. When the dentist has to explain in detail to a new receptionist or practice manager his exact duties and functions, uncertainties may arise. If the new person is replacing someone who did the job well for a number of years, the dentist may well, having delegated a proportion of the tasks, be uncertain of the precise details of how those tasks are actually performed.

Most dentists have some experience of employing staff to assist with the clerical work in their practice. This may be done entirely by a practice manager or by a combination of a practice manager and one or more dental surgery assistants. Usually there is more than one member of the ancillary staff with knowledge of the office procedures, so if one member of staff leaves, the other staff help in training the successor. So the dentist tends not to have to bear the full burden of staff training. However, it is instructive to envisage a scenario in which all the staff with any knowledge of the office procedures in your practice have just left you. You have

taken on replacements, but none of them have any experience of any office procedures, let alone those of a dental surgery.

Your new staff can read and write and perform arithmetic very accurately and quickly, and are very obedient, carrying out exactly everything you tell them to do. Furthermore, they only need to be shown once how to perform a task; they never forget subsequently what they have been told. However, they have their drawbacks. They need to be told everything; they seem to have no initiative or common sense. For example, they might book an examination appointment for a patient on Christmas Day, because it falls on a Thursday and you only told them not to book appointments at weekends. Or, because you instructed them to work out how much is owed by every patient who has just finished a course of treatment, then send an account, they post off bills for £0.00 to all the exempt patients. Or, when your local MP comes in for an examination, they ask him whether he is receiving supplementary benefit, because you told them to find out whether people were exempt from NHS charges.

At this point the reader will doubtless protest. Surely no-one would employ such people in their practice! However, *a computer is the ultimate in inexperience*. It has precisely no knowledge of how any dental practice works. It must be told everything it needs to know, and systems analysis is the only way of finding out what it is that the computer needs to know.

Expanding on the earlier definition of a system, the system, ie the dental practice, is concerned with inputs, processing and outputs. The inputs are oral or written communications between patients, staff and dentists. For example, someone who has not previously attended the practice may write or telephone, requesting an appointment for an examination. This communication is an input to the system. The processing of this input takes the form of scanning the appointment diary to find a suitable space, storing the patient's name in the appropriate space in the appointment diary, and producing an output in the form of a printed appointment card which is then sent to the patient.

It is convenient to break the large system (ie the entire practice) down into smaller *subsystems* which can be more easily analysed. Each subsystem contains a number of *entities*, ie objects

involved in that system. For example, the appointments diary subsystem involves patients, dentists, and appointments. Every entity has a collection of *attributes*, which are features used to describe and identify a particular example of that entity. For example, the entity PATIENT will have a number of attributes including Name, Address, Date of Birth, and Telephone No. Entities have relationships between themselves and other entities.

The process of systems analysis is primarily concerned with identifying all the subsystems, entities, and attributes within the dental practice. Furthermore, efforts must be made towards determining relationships which might be useful to establish, even though they exist only as indirect relationships in the present manual system.

A systems analysis of that most hard-to-define organisation, the average dental practice, might reveal the structure shown in Figure 2.1. The dental practice is a system with three principal subsystems which overlap to some degree. There is interaction between it and other outside systems, including the DEB, FPCs and laboratories.

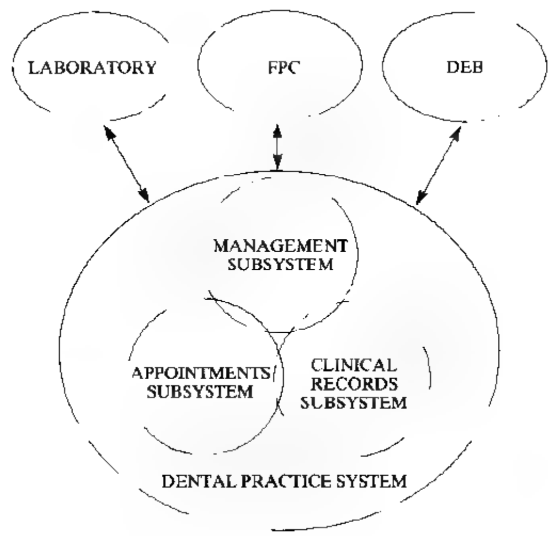

Figure 2.1 The Dental Practice System

SUBSYSTEM COMPONENTS

An outline of the various components of each subsystem might appear as follows:

Practice Management Subsystem

1 Accounts:
 Practice income
 Practice expenditure
 Patients' debts
 Receipts – NHS
 Receipts – private

2 FP17:
 Current – awaiting submission for approval
 Current – submitted, not yet approved
 Current – approved
 Completed – awaiting submission for payment
 Completed – submitted, not yet paid
 Completed – paid

3 Dental materials:
 Current stock levels
 Stock currently on order
 Reorder levels

4 Management information:
 Income received for each dentist
 Hours worked by each dentist
 Breakdown of treatment performed by each dentist
 Patient debts owed to each dentist

5 Laboratory information:
 Analysis of work by each dentist
 Current stage reached in each case
 Work due in

Appointments Subsystem

1 Current appointments:
 Type of appointment
 Linked or single

2 Day list creation:
 List for each dentist or hygienist

3 Failure rates:
  For whole practice
  For each dentist or hygienist

4 Recall:
  3 monthly
  6 monthly
  Yearly
  Other interval/no recall

Clinical Records Subsystem

1 Registration details:
  Name
  Address
  Date of birth
  Telephone no (home)
  Telephone no (work)

2 Dental charting details

3 Medical history

4 FP17:
  Treatment complete
  Failed to complete
  Sent for payment
  Sent for approval
  Approved

5 Treátment details:
  Past
  Current
  Date of last examination

6 Financial:
  Past debts
  Current debts
  Current treatment – total cost to date
  Current treatment – patient's charge
  Current treatment – amount paid to date

The above items are simply a guide to the minimum level of information to which a dentist might require access. Obviously the details of these requirements will vary between practices, but

they form a basis for considering how required information is currently derived in a manual system.

Several new terms now need to be introduced. Suppose a dentist wishes to send reminders to patients who have not attended the practice for over a year. He might say to the practice manager: 'Please search through all the FP25 folders, check the date of the last visit on each one, and if that date was more than one year ago, retrieve the folder.' In a computerised system, he would say, 'Search the patient *database*, retrieving each *record* in which the contents of the last-visit-date *field* is over one year ago'.

A *field* is a reserved space for an individual piece of data, with predetermined length and position, in other words a slot used for the description of an attribute. On an FP17, for example, there is a 'patient's date of birth' field which is always in the same position on the form, and is always six spaces long: two digits each for the day, month, and year of birth.

A *record* is the grouping of data relevant to one instance of an entity in the system. So an entire FP25 is a record; each record contains the same fields in the same positions, but the contents of these fields vary for different patients.

At this point the reader may be disturbed by the statement 'each record contains the same fields in the same positions'. That is not strictly true of FP25s! Certainly, these folders are all printed with the same fields in the same positions. But some patients have two telephone numbers, both of which are to be recorded. On an FP25 record card, this is coped with by simply squeezing the second number underneath the first one. But the number and size of fields in a computer record cannot be violated in this way; you have to decide in advance how many telephone numbers you are going to provide slots for in your patient record, and having made this decision, all instances of that record will have the same number of slots. This underlines the importance of thinking ahead and making sure that the records in the system will be capable of storing all the information necessary to support the required functions.

A *database* is in effect a filing cabinet. It contains a number of instances of records which may be of different types, but with the

constraint that all instances of a given record type will contain the same fields, the contents of those fields being variable. As an example, suppose a dental practice has one large filing cabinet in which all the patients' record cards are filed alphabetically, with both private and NHS patients filed together. That entire cabinet can be thought of as a database containing two types of record, private records and FP25s. Every FP25 will have the same fields as the other FP25s, and every private record card will have the same fields as all the other record cards, but there need be no similarities between the two types of record, although in practice obviously there will be.

FLOWCHARTS

Having established the major entities in a subsystem and identified their attributes, the relationships between them can be determined through a detailed consideration of the functions in that subsystem. An effective means of analysing functions is through *flowcharts,* which are a convenient diagrammatic method of representing information flow within a system. As an example, consider the process of making simple recall appointments. A number of steps are involved (shown in Figure 2.2).

Flowcharting helps the understanding of problems encountered in practice management by showing clearly what tasks are performed at the most basic level. Typically, while developing a flowchart for a key function, the dentist may be struck by how complex it is and, often, by how many unnecessary steps he can spot. Flowcharting allows the most time consuming or difficult tasks to be identified; alternative methods can then be postulated by drawing a revised flowchart diagram, to assess what effect any proposed changes might have on the system. No attempt should be made to computerise any function within the practice until the current manual system is clearly understood. Manual methods must themselves be optimised before they can serve as a basis for computerisation.

WORK MEASUREMENT

Another important investigation is work measurement. The cost of operating manual office systems arises through wages, not

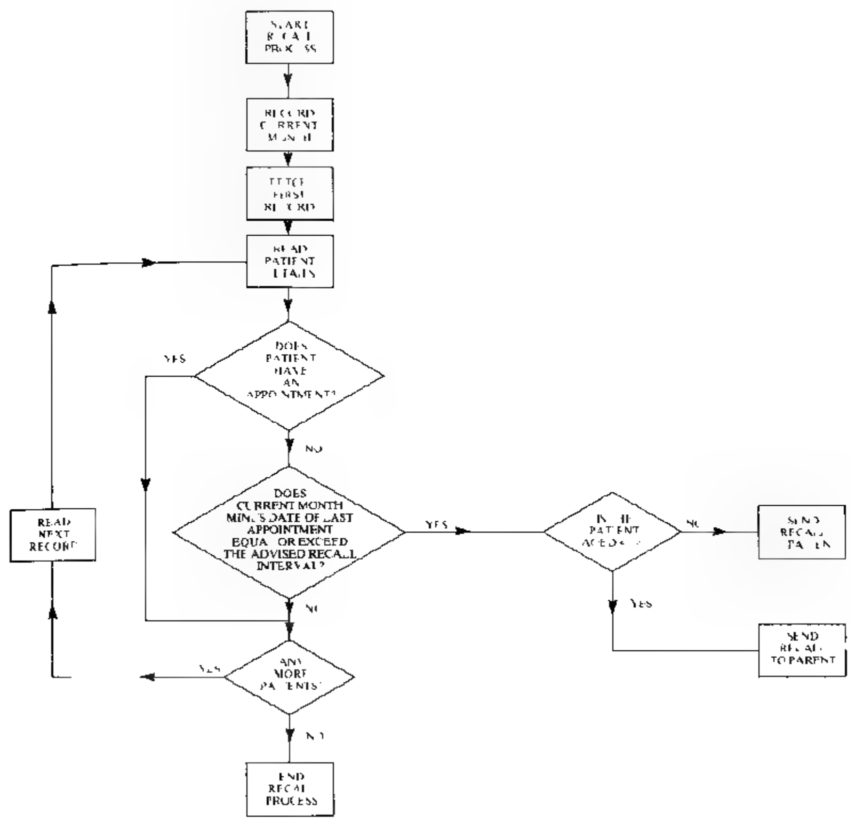

Figure 2.2 The Recall Process

through raw materials. Consequently, it is worth analysing how much time the practice staff spend in their various clerical duties, to determine which take up the most time. This can be achieved through logging the activities of all staff over a period of, say, a week. If a member of staff spends an hour per day looking for lost FP25 record cards, the underlying problem must be solved before attempting to computerise the records. It is erroneous to believe that computerisation will eliminate the problem of lost record cards. It may well be that the patient's name has been wrongly spelt on the card, leading to its being filed in the wrong place, and mistakes of this sort are no less likely to arise in a computerised record system. If the dentist or his staff are spending large

amounts of time 'firefighting', then there are fundamental problems which must be uncovered and solved before computerisation.

The work measurement study also has the advantage of involving all staff members in the evaluation of the present practice situation, and gives them a chance to record their own views of problem areas and possible solutions. It has long been recognised that a new computer system will not be successful unless it gains full acceptance by the staff who will use it. If those individuals whose working routines are most affected by computerisation have not been involved in the evaluation process, they will often object to having a new way of working thrust upon them. This may seem paradoxical since computers are designed to make work easier and more enjoyable, but there is still considerable hostility shown by many people to computers; partly due to fears that the new machine will displace them from their job (a highly unlikely outcome in a dental practice), and also, perhaps even more importantly, because the decision to implement a computer system seems to imply that there is something wrong with the existing manual system.

A practice manager who has been conducting the administration of the practice efficiently over a number of years and knows every last detail of the workings of the practice, even better than does the dentist, may well resent the challenge to authority that a computer system appears to provide. Needless to say, the significance of these considerations will depend largely on the personalities concerned, but by involving staff fully in all the stages of systems analysis, and by canvassing their ideas for improvements to the system, such problems will be minimised. It is worth pointing out to the staff that instead of their tasks becoming deskilled by computerisation, as is so often believed, their job may acquire more status, since less of their time will be taken up with routine clerical tasks, allowing them to direct more effort towards improving the practice image, perhaps as dental health educators, or by generally being available to advise and reassure patients.

When a thorough analysis of the current workings of the practice has been completed, the dentist will be in a position to

optimise fully the manual tasks performed in the administration of his practice. Even if he decides not to proceed with computerisation, he will still benefit from the improvements in efficiency resulting from amendments to the routine in the light of the study. Up till recently, a very good case could be made for choosing at this stage to adhere to a traditional fully manual system, owing to the relatively high cost of computer hardware and software, and the general lack of experience that the profession had in the use of computers. Today however there are very few practices which could not justify the computerisation of at least some of their clerical activities. This may seem a difficult statement to justify, given that probably fewer than 20% of practices use a computer at present. But the cost of business computing is now so low that even the smallest or least profitable practice can afford it.

ASPECTS OF COMPUTERISATION

It would be inappropriate for this book to recommend any specific set of administrative functions which should or should not be computerised, because what is appropriate and necessary for one practice may well be entirely inapplicable to others. Instead, the major applications will be considered, with arguments for and against, and the reader will have to make his own decision as to which of these he will implement, based on the findings of the systems analysis he has performed. A further decision must then be made as to whether to implement all the required functions in a single integrated system, or to start with perhaps one or two basic applications, adding more later.

The arguments in favour of implementing a single comprehensive computer system to fulfil all the major administrative requirements of the practice are powerful and cogent. Only by determining in advance the overall list of functions in the system, their components, and the interactions between them, can a fully integrated suite of computer programs be devised. The advantages of integration are that the same data can be shared between different programs, thus eliminating duplication of data which is costly in terms of storage and time taken for input. In an integrated system, a single database stores all the records required by the system in such a way that any combination of

fields from one or more records can be accessed in any order by applications programs according to their data requirements.

To illustrate this, suppose that a non-integrated, piecemeal approach to computerisation has been pursued. The practitioner has decided it would be advantageous to have a computerised list of all his patients, with details of their names, addresses, and dates of their last appointment, so that he can send recalls at appropriate intervals. He designs a system containing a single record type, called PATIENT, which has the following attributes:

PATIENT: First name
Second name
Address
Date of birth
Date of last appointment

Each occurrence of the PATIENT record is stored in a file, which is simply a sequentially arranged collection of record instances So a simplified program to send six-monthly recalls might have the following logical structure:

1 Open the file of PATIENT records

2 Read the first record

3 If date of last appointment > 6 months ago then send recall

4 Read the next record

5 If end of file reached then finish, else go to step 3.

This works so well that the dentist decides to use his PATIENT records file to provide him with more information. He decides to write another program to analyse the different age groups attending his practice so that he can target the practice image more accurately towards the largest of these groups. He writes another program, containing suitably named counters for each age category, the contents of which can be retrieved at the end of the program run:

1 Open the file of PATIENT records

2 Read the first record

3 Set all age category counters to 0

4 If date of birth between 1972 and 1988 add 1 to U16 counter

5 If date of birth between 1963 and 1971 add 1 to 16–24 counter

6 If date of birth between 1953 and 1962 add 1 to 25–34 counter

7 If date of birth between 1943 and 1952 add 1 to 35–44 counter

8 If date of birth between 1933 and 1942 add 1 to 45–54 counter

9 If date of birth between 1923 and 1932 add 1 to 55–64 counter

10 If date of birth < 1923 add 1 to over 65 counter

11 Read next record

12 If end of file reached then finish, else go to step 4.

By now our dentist is so impressed with his new computer that he thinks of more and more ways of using the data stored in his PATIENT file. He decides that sending birthday cards to his young patients would improve the practice image. His next program works like this:

1 Open the file of PATIENT records

2 Read the first record

3 If day and month of birth are within 7 days of today's day and month,
and current year – year of birth < 14 [patient is under 14]
then send birthday card

4 Read next record

5 If end of file reached then finish, else go to step 3.

More and more programs are written, each of which accesses the file of PATIENT records and processes some of the data within each record in a particular way. Then the practice manager suggests an improvement. If each PATIENT record had two extra fields, these could be used to store the date and time of that

patient's next appointment. This would bring great benefits. For example, if a patient telephoned to ask what the date and time of his next appointment was, a very simple program would reveal the answer, without tedious thumbing through the pages of the appointment book:

1 Open the file of PATIENT records
2 Read the first record
3 If PATIENT.FIRST NAME = ENQUIRY.FIRST NAME
 and PATIENT.LAST NAME = ENQUIRY.LAST NAME
 then retrieve PATIENT.APPT DATE, PATIENT.APPT TIME, finish
 else read the next record
4 If end of file reached then finish, else go to step 3.

Although the addition of two fields to the PATIENT record may seem trivial, this is not the case. Not only would this involve amending all the records in the PATIENT file, but also all the programs accessing that file would have to be rewritten, because programs written using standard techniques can only identify the fields they require by the position of those fields within the record. Therefore the layout of the record has to be made known to the program. So programs expect records to be a particular length, and also that the constituent fields remain in constant positions within that record.

Our hero decides against altering his PATIENT record file, since the thought of having to rewrite all his programs is too much to bear. So he decides to create an entirely new file of APPOINTMENT records, each with four fields:

APPOINTMENT: Date
 Time
 Patient's first name
 Patient's last name

Programming the required enquiry is then simple enough, along the following lines:

1 Open the file of APPOINTMENT records
2 Read the first record

3 If APPOINTMENT.FIRST NAME = ENQUIRY.FIRST NAME
 and APPOINTMENT.LAST NAME = ENQUIRY.LAST NAME
 then
 if APPOINTMENT.DATE > today's date (in the future)
 then retrieve APPOINTMENT.DATE, TIME, finish
4 Read the next record
5 If end of file reached then finish, else go to step 3.

But there is inefficiency inherent in this approach. Both the PATIENT and APPOINTMENT record files store the patients' first and last names. This means that more storage space is needed. The basic problem is that of duplication of data, ie certain fields (in this case first and last name) are repeatedly stored in different records within a collection of files. This is very wasteful of storage space and results in unnecessarily large files which take longer to process, degrading the performance of the system. Furthermore, the physical separation of the different record types in their respective files means that information cannot be retrieved directly on the basis of comparison of the contents of an occurrence of one record type with those of an occurrence of another record type.

For example, suppose the dentist wished to find out how many children under 16 he had seen over the previous week. If he had added the appointment.date and time fields to his PATIENT record, a very simple program could have been written, again using a suitably named counter variable:

1 Open the file of PATIENT records
2 Set U16 counter to 0
3 Read the first record
4 If PATIENT.APPT DATE fell during the previous 7 days
 and year of birth > 1972
 then add 1 to U16 counter
5 Read the next record
6 If end of file reached then finish, else go to step 4.

Observe that this process only requires one pass through the file of PATIENT records. But the appointment date and time fields are not contained in the PATIENT record, but in the APPOINTMENT record. So in order to find the records relating to children seen during the last week, first the APPOINTMENT records file has to be searched, and the names retrieved of each patient with an appointment during the previous seven days. These have to be written to a new temporary file, then the APPOINTMENT file is closed, the PATIENT file is opened, and the name of each record in the temporary file has to be accessed from the PATIENT file, the date of birth noted, and the counter incremented if that patient is under 16. Without elaborating on the details of how records are accessed, it can nevertheless be seen that this is a far more complex set of processing steps, necessitating the creation of an intermediate file.

Alert readers may have spotted another serious problem. In the example where the patient telephoned to inquire the date and time of his next appointment, his first and last names were used as the 'template'; the appropriate record was retrieved by matching the contents of its first and last name fields to the first and last names of the patient enquiring about his appointment. But what would happen if two patients with the same names both had appointments booked? This is not an uncommon occurrence. Every dentist must have looked down his day list at some time and seen two patients with the same name. Sometimes these patients both turn up together, causing much confusion when two people get up from their seats on hearing a single name called. But human beings, though easily confused, can usually resolve problems of this nature by applying common sense. We look at the two record cards. If the two John Smiths have widely different dates of birth, we can deduce which one is which by looking at the two people who get up when that name is called. If this is not the case, then we can distinguish between them by asking the address of one of them. This may seem obvious, but a computer has no common sense. If it is confused, it will stay confused. Therefore the system must be able to distinguish each patient from all the others. Clearly the name fields are insufficient for this purpose, even though they are quite adequate 99.9% of the time.

This is a problem which has always beset the designers of

computer systems; every record relating to a patient, customer, mailshot addressee, or any other entity which needs to be distinguished from other occurrences of the same entity type, must have some form of unique identifier, and names alone are not enough. The term *record key* relates to that field or combination of fields in a record which serves this purpose. A number of approaches have been used to implement keys.

In the case of the PATIENT record, if the combination of first name, last name, and date of birth were used, we would expect to be able to identify uniquely a given record occurrence. The chances of two people in the practice with the same names and date of birth are remote. But, in a very large practice, it could possibly happen and it may be necessary to introduce further fields, such as the address, into the key.

An alternative approach is to give each patient a unique number on registering their record in the system. The practice must keep a written record of this number, usually on the record card. No matter how large the practice, the supply of available numbers will never be exhausted, therefore this method is guaranteed to find the exact record, but it is highly unlikely that patients will remember their own number, so this is hardly a suitable key on which to search for a patient's record on the basis of information that the patient himself provides. The great advantage of a numerical key is that it takes up very little space in a computer record compared to other fields such as names or addresses. Therefore, if each PATIENT record has a numeric key field, and this same field is also included within every APPOINTMENT record, each record type can be accessed on the basis of the contents of the other.

In practice it is usually desirable to have a unique numerical key so that the different record types can be related to each other with minimal additional storage of information within each record occurrence. This does not prevent searches through individual files being performed using values of more meaningful fields such as names. But for rapid searching through a file, the key used should appear within the records in the file to be searched.

The above example illustrates the importance of deciding at the

outset which functions are to be computerised or which might be considered for computerisation in the future. Only then can suitable record structures be designed. Provided that a suitably comprehensive record structure is provided at the outset, it does not matter whether or not the more esoteric processing requirements are programmed initially; further programs can always be written later, providing the necessary data is available, and presented in such a way as to allow data from different records to be combined, without unnecessary duplication. This is achieved through the use of databases rather than simple files.

Although databases were likened earlier to filing cabinets containing instances of various types of record, they have another important characteristic; instances of a given type of record within a database can be linked to instances of other types of records. This is achieved by means of a pointer field within each record, which contains the address, or storage location, of the record to which it relates.

Back to the previous example. Suppose the APPOINTMENT record is given a pointer field which indicated the address of a PATIENT record to which that appointment related. A given record in the PATIENT file can now be accessed directly on the basis of the contents of a field within an APPOINTMENT record. Of course, we would also require, given a PATIENT record, to be able to find out what APPOINTMENT records related to that patient. So each PATIENT record would also have a pointer field, the contents of which would indicate the address of any APPOINTMENT records relating to that patient.

Another advantage of the linking together of different record types within a database is that constraints can be enforced governing the way in which the record types are related. For example, a given appointment can of course only relate to one patient, but a patient could hold a number of different appointments concurrently. All database management software supports the enforcement of such real world constraints.

Database systems are highly complex and there is certainly no need for the dentist to know much about them, other than to appreciate that they allow data to be shared between programs, thus avoiding unnecessary duplication and allowing the data

requirements of new applications to be satisfied without having to create any new stored files or amend the record structure of existing files. But the price of these advantages is that the structure, or schema, of the database must be clearly determined at the outset, and record types and the relationships between them designed accordingly.

What then are the disadvantages of this comprehensive approach to computerisation? The most obvious one is that of complexity; a considerable amount of work is involved in designing a fully integrated system to support all the major administrative data processing requirements of the average practice, and few dentists would be prepared to acquire the necessary skills or to spend the time necessary to do this themselves. It must be stressed that designing a computer system is harder and more time consuming than actually writing the programs. Few people outside the computer profession are aware of this; there is a widespread belief that the construction of computer systems revolves around a mysterious 'black art', known as computer programming. In fact, the task of programming is simple compared to those of analysis and design. The systems designer needs to be genuinely creative; the programmer merely takes written instructions from the designer and translates them into code.

Concomitant with the complexity of such comprehensive systems is of course high software cost, since the more effort that has gone into the design and construction of the software, the higher will be the costs incurred. However, the proportion of the development cost that must be passed on to the purchaser will vary according to the anticipated number of purchasers. If a practice engages the services of a software house to design and implement a bespoke comprehensive computer system, it will have to bear the entire development costs by itself and this is unlikely to be a viable proposition for the average practice, although it may well be the only solution for very large establishments with six or more dentists. Systems analysts and programmers consider themselves to be professionals as much as we do ourselves, and their services do not come cheaply. The alternative therefore is to select from the available commercial packages.

It is reasonable to assume that within the next ten years, the majority of dentists will be using computers to assist with the administration of their practice. Having discounted the possibility that significant numbers will actually design and build their own computer systems or have bespoke systems constructed, it follows that most dentists will need to be able to evaluate the commercial packages on offer, in order to select the most suitable system We consider the evaluation of computer systems in Chapter 5, but first – in the next two chapters it is necessary to outline the major administrative applications.

3 Possible Computer Applications

GENERAL

This chapter details the major applications in practice management which are realistic targets for computerisation at the present time, taking into account costs and current hardware and software capabilities. The reasons for considering computerisation will vary enormously between different practices, due to differences in their size, location, patient profile, and profitability, as well as to the differing attitudes that individual dentists have towards the new technology. There is even less uniformity in the way different practices are managed than there is between the ways in which dentistry is performed within them, and obviously this book can do no more than attempt to define the common ground.

THE SCICON STUDY

The first and only large-scale study to date of the requirements of dental practice computer systems is the report *Computing in General Dental Practice*, by Scicon, a major computer consultancy. (This was commissioned in 1981 by the British Dental Association, following a similar study carried out for the British Medical Association by the same company.)

The stated purposes of the Scicon study were as follows:

1 To give guidance to dentists considering the possible use of computers, and to enable them to avoid the pitfalls to which first-time users of computers are prone.

2 To provide guidance on the type of computer systems, their size and scope, which would be of most benefit to dentists.

Although improvements in technology and reductions in the costs of hardware since 1981 have made the costs and detailed specifications in the Scicon report outdated, it is nevertheless still worthy of study by those interested in the topic, since it was the first serious attempt to analyse the information management requirements of British dentists. Most of its observations still have relevance today, the main difference being that problems in practice automation have become easier to solve, mainly through improvements in hardware, and, equally importantly, through accumulated experience of the use of computers in dental practice. The report identified various functions or activities, common to all dental practices, which were considered to give rise to problems in practice management. These were divided into three major categories, each comprising a number of functions, as follows:

1 Appointments:
   Making and booking appointments
   Issuing recall notices
   Printing dentists' work lists

2 Clinical record keeping:
   Storing patients' details
   Charting

3 Practice management:
   Fees accounts analysis
   Practice accounts
   Stock control
   Claims for treatment

These categories are now considered in detail.

APPOINTMENTS

Initial appointments

Although many dentists are willing to see patients on an emergency basis, and some ensure that sufficient time slots are left vacant during their working hours in order that casual patients may be treated, in most practices the majority of patients are seen by appointment. It is generally agreed that an appointments system enables the dentist to plan his work better and

reduce the amount of time that patients have to spend in the waiting room. Furthermore, it enables better use to be made of the available resources, namely available surgery time and the use of a dental surgery assistant.

However, it is worth noting the disadvantages of appointments systems. The most obvious is that staff have to be deployed to answer the telephone and book appointments. Also it has been suggested that appointments can make it more difficult in some cases for patients to see a dentist. The elderly and patients in social classes 4 and 5 are said to be disadvantaged because they are less likely to have telephones. Middle-class patients are said to be better able to negotiate with receptionists in order to get an appointment at the time of their choosing. Similarly, middle-class patients are less likely to lose pay if they take time off work to visit the dentist, thus allowing them a better choice of appointments. These points are worth bearing in mind when considering how much of the dentist's available time should be spent seeing patients by appointment.

The conventional manual appointments system usually relies on a large loose-leaf folder, each page being printed quite simply with lines across and columns down. Times of the day are noted down the page and the names of the dentists or hygienists in the practice listed across. Appointments are booked by entering the patient's name, perhaps with a brief code to indicate what the appointment is for, such as 'EX' for examination, 'F' for fillings, etc, in the appropriate time slot for the clinician requested.

This very simple technology is inexpensive to implement, and can be used in a variety of ways. Since requests for appointments are normally received over the telephone or in person, the appointment book is kept beside a telephone on the reception desk. The book has the virtue of being able to be referenced by a number of people concurrently. Thus different receptionists could be dealing with different requests simultaneously; for example, one across the counter and another over the telephone, both using the same appointment book without any need for duplication of the data contained therein. Although time slots are usually fixed (for example, by each slot representing a ten-minute time interval), flexibility can be easily achieved through using multiple consecutive slots for longer appointments.

Another advantage of the familiar loose-leaf appointment book is that it allows up to a whole week of appointments to be viewed at once without turning a page. Since most computer screens can only display 24 lines of up to 80 characters across, it will probably be impossible to show more than one day's appointments at a time on a screen. Consider also that a computer terminal at the reception desk is likely to be used for other functions, such as writing letters, as well as for appointments, access to the different functions being via a menu screen. Obviously a single terminal will be unable to display two such tasks concurrently in any useful format, so effectively it would be impossible to book appointments via a given computer terminal while someone else was using it for something else. So, in a fully computerised appointments system there must be a terminal dedicated entirely to appointment booking.

A criticism often levelled at appointment books is that they are liable to become illegible through undisciplined alterations. To quote from the Scicon report: "In not a few practices, the state of the appointment book, with frequent amendments, deletions, and alterations, was awesome." But if all appointments are written in pencil, they can be rubbed out neatly if amendments are to be made; therefore this need not be a serious problem if the book is used in a disciplined manner.

However, there are deficiencies inherent in manual appointment systems. For example, if a patient requires a number of linked appointments, perhaps arranged so that he can be seen by both the hygienist and the dentist at the same attendance, the scheduling of consecutive appointments with more than one clinician is difficult, requiring a time-consuming search through several appointment books. A computerised appointments system would be able to book even complex combinations of appointments very rapidly. Another problem frequently arising is that of the patient who telephones or calls in saying that he is unable to remember the time of his next appointment, or even, in a multiple practice, the name of the dentist he is to be seen by. Again this type of enquiry can involve much time consuming searching through one or more appointment books, but is easily answered by a computer system.

There are further advantages to be gained from the computerisation of appointments. If the system knows details of all the appointments made, the practice activity can be monitored. The system can log which times and days of the week are most popular, which dentists in the practice have the highest proportion of patients failing to attend, and generally allow a 'demand pattern' to be established which will enable surgery hours and scheduling of clinician time to be reviewed objectively.

Analysis of attendance patterns will also identify patients who habitually arrive late or fail to attend for appointments. Such patients can be allocated shorter appointment slots to minimise wastage of surgery time in the event of non-attendance.

Rescheduling of appointments is sometimes required at short notice for a variety of reasons, staff illness being the most common. A computerised appointments system would be able to retrieve rapidly the telephone numbers or addresses of all the patients with appointments on a certain day, making the task of contacting those patients at short notice much easier.

Recalls

Attention has already been drawn to the usefulness of computers in providing a reliable system for arranging recalls. In the present situation, where many practices are experiencing a reduction in the numbers of patients attending, it is generally considered more important than ever before to maintain contact with patients and encourage them to attend regularly. It has been shown that a practice computer system providing recalls can pay for itself if it causes just three patients per week to attend who would not otherwise have been recalled. Thus the implementation of an effective recall system should be given high priority; indeed, a recent survey indicated that 75% of dentists felt that a recall system was essential.

A common manual method of recalling patients is to write out the patient's name and address on a pre-printed postcard at the time of the last appointment in a course of treatment. The postcards for each month are filed away together and retrieved six months later, and posted off. Each card may request the patient to call to make an appointment, or alternatively an appointment

may be written on the card and the patient asked to cancel if it is not suitable.

This method is certainly cheap to implement, and is reasonably effective. However, the receptionist has to remember to write out a recall card every time a patient completes a course of treatment, and there is a danger that whole batches of cards may be lost. Also the system is rather inflexible. It works well as long as everybody in the practice is to be recalled at six-monthly intervals. But this blanket approach to recall intervals is falling out of favour. Some patients may need to attend the hygienist every three months, for example. Others, with excellent oral hygiene and no caries or restorations may only need to attend once a year. Another shortcoming of the postcard as a means of communication is that it tends to be impersonal and rather terse, simply stating: 'Dear Sir or Madam, Your check-up is now due. Please call to make another appointment' – or words to that effect.

We would expect a computerised recall system, as well as being capable of noting the appropriate recall interval from the patient's record and initiating recall notices accordingly, to create these documents in the form of personalised letters rather than postcards. The patient's name is retrieved from his record and this is used to give the appropriate salutation. Different wording may be used in the text of the letter according to whether the patient is young or old, NHS or private, or on the basis of other attributes. Notices about the facilities offered at the practice, or other patient information, can be included in the letter, and can be readily altered or updated.

The flexibility and ease with which letters and other documents can be created using computers is achieved through the technique of word processing, which is the use of computers to create, view, edit, store, retrieve and print text. Although word processing is one of the most basic computer applications, and quite sophisticated word processing programs have been written even for the smallest home computers, it is nevertheless one of the most impressive. The advantages of the word processor over the typewriter are enormous.

As text is typed into a computer running a word processing

program, it is displayed instantly on the screen. Carriage returns are automatic, and deletions and corrections can be made to the text on the screen before committing the result to hard copy by using a printer. Sentences and paragraphs can be added, deleted, copied, or moved around in the document as required. The text can also be saved to disks for permanent storage, so that the same document can be reloaded into the computer without any need to retype it. Instructions concerning the output format can also be specified. For example, the system can be instructed to print headers or footings automatically on every page of a document – ideal for printing a practice logo, address, or a dental health message at the top or bottom of all recall letters. Margin settings and spacing can be specified, and different font sizes and styles can be invoked for individual parts of a document. Similarly, different words or phrases can be underlined or made to appear in bold face.

In a word processor-based recall system, appropriate pre-recorded paragraphs can be selected from a number of paragraphs held in storage, and assembled to produce the required document for a particular patient. For example, recall letters to young adult patients, most of whom tend to be conscious of their image, might be worded to emphasise the importance of regular appointments with the hygienist in maintaining good overall appearance and a nice smile. Patients who have failed appointments in the past might be given polite warnings that they may be charged for further failures. Patients who are known to be particularly anxious can have specially reassuring letters; personal touches of this nature can be highly effective in communicating to the patient just how much the workers in the practice care for him as an individual, and thus can help considerably in building a favourable practice image. To quote from the Scicon report: "It is recognised by most dentists that the management of recall notices is particularly suited to the use of the word processing facilities provided by a computer system."

To obtain the full benefits from word processing, the use of appropriate stationery is important. Many systems print out addresses on sticky labels, which have to be matched to the appropriate letter, then stuck onto an envelope. But by using window envelopes, much unnecessary work can be avoided; only

the letter needs to be printed, and the patient's name and address on the letter appear through the window when inserted into the envelope.

Word processing will have many other uses in the practice besides preparing recall letters, since there are a number of documents which will benefit from being neatly and rapidly prepared and printed. Appointment cards, post-operative advice sheets, health education newsletters, referral letters, wages slips, and laboratory instruction slips are just a few examples. And word processing software is becoming more and more sophisticated. Most of the popular word processing packages have a spelling checker which detects incorrect spellings and suggests alternatives. The latest word processing programs sometimes have an inbuilt thesaurus as well, which will suggest alternative words or phrases at the user's request; therefore one need never be 'lost for words' again!

Work lists

It is standard practice each day in manual systems to copy from the appointment book a list of patients due to attend each dentist or hygienist on that day, with the time they are due, and usually also a brief indication of the purpose of the appointment; this list is then kept in the appropriate surgery. This is a time consuming business, particularly if the dentist is seeing a large number of patients for examination only, or if there are several dentists or hygienists in the practice. A computerised appointments system should be capable of printing patient lists for any day or group of days for each clinician. This activity is related to the appointments analysis functions mentioned earlier.

In designing the appointments subsystem, provided that the members of the practice are willing to maintain a written appointment book, appointment information can simply be held in suitable fields within the patient record. This will support all the non-time-critical applications, including recalls, day list printing and analysis of attendance patterns, which can be left to run overnight or during periods when the computer is not in use for other purposes, or in the case of a multi-tasking computer system (one which can run more than one program concurrently)

these could be run as background processes since they need no interaction from the user. But such a system will not be suitable for booking appointments. Appointment booking has to be carried out interactively and in real time. In other words, the computer must respond instantly to a request for an appointment booking; it would not be acceptable for the receptionist to wait while the computer searched through the patient records file in order to find out which appointment slots were already booked, since this would take longer than a manual system. If a computer based appointment book is considered essential, an appointment record must be considered as an entity in its own right and maintained as such. This will require more storage and processing power in order to give acceptable performance.

Before leaving the subject of appointments one further nail must be driven into the coffin of the computerised appointment book. So far we have been considering which of the clerical functions of the practice are the most important for computerisation. But no attempt has been made to distinguish between functions which are essential (ie so fundamental that no practice could exist without them) and those which are not. While a recall system is useful, practices can and do function perfectly well without them. But a practice whose appointment book suddenly goes missing is in serious trouble. While computers are highly reliable machines, they do occasionally fail and it is naive to assume that a computer system will never let you down. And power supply failures are not uncommon. If a conventional appointment book is maintained, the practice will not grind to a halt every time the computer goes down. Bookings can still be made in, and enquiries answered from, the appointments book, and the computer files can be updated later as necessary.

It must be stressed that advice given in this book cannot be equally applicable to all practices whatever their size. It may well be that in a very large multiple practice, with six or more dentists working in the same building, the problems involved in maintaining the required number of manual appointment books are so great that computerisation is justified (Lewis, 1984). However, for the majority of dentists, who work in relatively small practices, a computerised appointment book will probably be of no benefit.

CLINICAL RECORD KEEPING

Under the terms of the NHS (General Dental Services) Regulations 1973, the practitioner has a duty to keep proper clinical records. Record cards (Form FP25) are provided for this purpose by the Family Practitioner Committee, but the dentist may if he desires use a form of his own choosing providing it gives substantially the same information. The record card remains the property of the practitioner who must retain it for a period (which varies with the treatment provided) of up to 2½ years. If requested to do so, he has to produce or send it to the DEB, the Local Dental Committee (LDC), or a Dental Reference Officer (DRO).

It is vital to keep full clinical records whether or not the patient has been accepted under the terms of the NHS, for obvious medico-legal reasons which will not be discussed here. A clinical record should at least comprise the following details:

First name of patient

Last name

Title

Address

Date of birth

Medical history

Treatment dates and details

Optional additional information may include costing details of treatment, patient's occupation, telephone number, preferred appointment times, source of referral, etc.

Storage problems, illegibility, ease of loss or misfiling, difficulty of sorting, and awkwardness of retrieval are all attributes of the FP25 which argue forcefully for its elimination, through the storage of clinical records in a computer system. A dentist in full-time general practice sees on average around 2000 different patients per year. Over a longer period, say five years, the number of patients seen could be as many as 5000. In a large group practice the number of records stored can easily be of the

order of 20,000. Not only does this require considerable storage space, but retrieval is a serious problem. To quote from the Scicon report again: "Records frequently get mislaid, and this, not unnaturally, is a source of much aggravation to all concerned." Undoubtedly, the ability to retrieve any record in seconds from a computer system which never mislaid any records would be a major benefit.

The FP25 in its familiar form does have some advantages, however, and these are frequently overlooked by those who have become beguiled by the concept of non-manual information storage methods. Firstly, it is, of course, provided free of charge; all the dentist needs to supply are pens and filing cabinets which are relatively inexpensive. Since the folder type FP25 can store many FP25 cards, and any radiographs and correspondence relating to the patient, it is highly flexible in its capacity to store information. Many will have seen FP25 folders containing details of all the dental treatment provided to a patient who has been attending a practice for over 30 years. Such folders may have become very bulky and rather unwieldy, but the important thing is – *they work*.

In most practices there is a degree of staff turnover, with the result that over the years, FP25s are written on by a number of different hands, some results being more legible than others. Charting is a particular problem, with frequent mistakes such as left/right transposition and incorrect notation, and a generally low degree of legibility. We would expect a computer system holding full clinical record details to provide graphic tooth charting, showing both required and completed treatment, and to maintain a chronological record of charting relating to previous courses of treatment. The standard of graphics should at least be sufficient to represent the 'box' type of chart used on FP25s and FP17s. It is worth noting here another advantage of the FP25 – sufficient space exists for up to nine historical charts on each card. The display of this amount of detail will not be possible on a single computer screen, since there will only be space for a maximum of three previous charts. As we will see in the final chapter, high-quality graphics systems capable of displaying more realistic images of teeth, and allowing periodontal status also to be depicted, are in an advanced state of development. The

information recorded on the current chart should be reconciled automatically against previous charts while it is being input during an examination or treatment session. This would prevent mistakes such as the accidental charting, at an examination session, of a cavity in a tooth that had already been extracted, or the recording, at a treatment session, of a restoration in a tooth that was not present.

It is worth considering the subject of dental charting in some detail. The formal notation which has long been adopted for the dental record and treatment plans lends itself to representation in a computer system. In the standard notation, three elements are involved:

1 A notation for the position of a particular tooth within the mouth, and the surfaces of the tooth concerned.

2 A notation for the various types of treatment applicable to whole teeth or their surfaces.

3 A grid representation, relating the above two types of notation to each other.

Clark and Dykes (1985) noted that there is no universally accepted system for dental notation, but indicated that this might not be too great a problem as computers can easily convert from one convention to another. The greatest agreement has been reached on the tooth numbering system pioneered by the Fédération Dentaire Internationale (FDI), based on a two-digit combination where the first digit identifies the quadrant and the second digit the tooth within that quadrant. The system can distinguish deciduous and permanent teeth. There are currently two methods for defining tooth surfaces, one using numbers and the other using letters, the latter being more popular in this country.

There is no agreed method of indicating the type of restoration either already present in a tooth or prescribed, but, recognising the need for a standard method of recording charting details if the record is to be used as a basis for preparing electronic estimates for submission to the DEB, the Department of Health and Social Security (DHSS) issued a document *The Patient Record System* in 1986, which specified a list of 25 two-character codes which

represent mnemonically the various conditions or types of treatment either already present or proposed. A further mnemonic code of up to seven characters is used to indicate the surfaces, if any, to which the treatment is applicable. Since the DHSS specification has been accepted as a basis for payment, it is likely to become a standard notation in the future.

The maintenance of information concerning the patient's medical history within a computerised clinical record would be highly beneficial. Firstly, the computer dialogue invoked to record new patients' details at their first visit can be designed in such a way as to prompt the dentist to elicit all necessary details of their medical histories, only accepting the new record when a response has been made to all the relevant questions. Having thus ensured that a full history is taken, further suitable prompts can be programmed to appear on the screen at subsequent examination visits, encouraging the clinician to check whether there has been any change since the last visit. In the case of patients with a serious medical condition, prominent messages can be displayed, perhaps in lurid colours, or flashing on and off, to draw attention to the hazard.

The earlier reference to the tendency of FP25s to grow very large where patients attend a practice over a long period of time raises the question of whether a computerised records system, if implemented, should be programmed to erase records after a certain elapsed time, perhaps only keeping records for treatment provided during the last five or ten years. Such purging of files is a very simple task for a computer, and can be done automatically at regular intervals without any intervention by the users. Certainly it would seem to be desirable for any practice to get rid of records relating to patients who have not attended for more than ten years, and most practices do this occasionally, searching laboriously through all their filing cabinets for such records. The decision as to how long to maintain records relating to patients who are regular attenders is a matter of individual choice. Many dentists have an aversion to the discarding of any records, no matter how old, and are quite happy to cope with swollen FP25s. Indeed there are some who consider a vast array of filing cabinets at the reception desk to be a visible hallmark of the success of the practice in attracting patients.

Other advantages of computerising clinical records relate to the improved capacity for the retrieval of summary statistics on treatment patterns and patient profiles. For example, if full details of all treatment were maintained in the computer system, suitable query programs would allow the practitioner to compare the average lifespan of restorations carried out using different materials, or assess the success and failure rates of various forms of endodontic therapy. Within a group practice, the prescribing patterns of different dentists could readily be compared, thus providing a useful basis for peer review.

This could lead to the involvement of practices in fundamental clinical research. There have been few longitudinal epidemiological surveys performed in general dental practice to date, but widespread computerisation of clinical records within practices would yield vast potential for improvement in our knowledge of disease patterns and the effectiveness of different therapies.

There are however a number of problems involved in fully computerising clinical records. Most of these problems arise from the vastly increased amount of information that needs to be stored and manipulated by the computer system when full details of past and current treatment are maintained. There are three direct consequences of increasing the amount of information held within a computer system:

1 More information requires more storage and a more powerful processor to maintain response times at an acceptably low level.

2 More information requires more effort to be input.

3 The more information held in a practice computer system, the greater the extent to which the practice relies on that system.

These problems will now be considered in detail. With the vast improvements in modern computer hardware, the issue of storage and processor power is becoming less important, although the addition of clinical records to a practice computer system still involves considerable additional expense. Firstly, such a system must be multi-user, with at least one terminal in each surgery, since clinical details must be visible during the

course of each patient's treatment. This requires a number of terminals which must be linked together in a network so that each terminal can access all the data stored in the system, regardless of where that information is held. In such a system, all the records are usually held on a hard disk in the terminal at reception, and the terminals in each surgery access these records remotely when required.

The difficulties inherent in computer networking are often not fully appreciated. Unlike the addition of an extension telephone or intercom, however, there is considerably more to networking than simply linking computer terminals by cable. Consider a simple example situation that could arise in a one-surgery practice, with a terminal at reception and another in the surgery, the records being stored on a hard disk at the reception terminal. When either terminal accesses a record from the disk, a copy of that record is read into the computer's main memory. There it is interpreted and the contents displayed on the screen. Access may be read-only (in which contents of a record are inspected and not altered) or read/write (in which contents are inspected, altered, and the record then replaced having been updated). A problem arises when users at both surgery and reception terminals each attempt to update the same record concurrently, and are unaware of the other's actions. For example, the receptionist might be recording a change of address, at the same time as the dentist is recording charting details for a patient. The result might be the creation of two new records for the same patient, one with new charting but the old address, the other with the new address but old charting. The more terminals there are in a system, the more likely the occurrence of such problems.

A computer network must therefore control access to data in such a way as to prevent concurrent updating of a record by more than one user. It does this by a complex series of locks which prevent one terminal from gaining read/write access to a record to which another terminal currently has read/write access. This commits the processor to performing large numbers of checking operations and inevitably slows the entire system down. But response time is even more critical in a network than in a single-user system, since it is undesirable for one terminal to have to wait before accessing data currently accessed by another.

Therefore the processing capacity of a network system needs to be much greater than that of a single terminal system. If the installation of a network system is being considered, it is essential to ensure that the processor will be adequate to cope with any further terminals that may be added in future without unacceptable degradation of performance.

The second major issue when deciding whether to include clinical details in the stored records is that of the effort required to input all the additional information. It will probably be no quicker to type in clinical details than it would be to write them on an FP25. If therefore the decision is taken to input all clinical information to the computer, it will take about the same amount of time to record as it would using FP25s. But this raises two further questions, the first being what to do with all the information already stored on existing FP25s. Depending on the size of the practice, the input of all existing records, including treatment done within say the last two years, will probably be an enormous task. Of course, the names, addresses, dates of birth, and date of last treatment for each patient are going to have to be typed in anyway if a recall system is to be implemented. Even so, the additional work of inputting previous charts, medical histories, and treatment histories may be a powerful disincentive to the maintenance of full clinical details on the computer system.

Assuming that a practice has fully computerised its clinical records, there is of course the problem of what to do with radiographs and correspondence. One of the most often cited advantages of fully computerised records is that FP25s can henceforth be banished from the overcrowded reception area and relegated to the basement. If radiographs of a significant number of patients are being taken on a regular basis for each patient, this is perhaps not such a good idea from the point of view of the member of staff responsible for filing. This may cease to be a problem when technology allowing the storage of radiographs as digitised images becomes widely available; this will be discussed later in the book, but radiographs as we know them will be with us for some time to come, and will have to be stored in FP25s for want of any more suitable method.

The third and most important consequence of the elimination

of the FP25 record is that the practice then becomes entirely dependent on the computer. The distinction between essential and non-essential functions of a practice was referred to earlier. There can surely be nothing more essential to the administration of a practice than its clinical records. One only has to reflect on how much disruption is caused by just one record going missing when it is needed, to appreciate what chaos would result in a 'paperless' practice in the event of a computer failure. Consider what happens in a conventional practice when an FP25, relating to a patient with an appointment, cannot be found. A duplicate has to be made out with all the patient's details and medical history, then the mouth has to be recharted before the dentist can proceed, unless he has an exceptionally good memory. Details of payments made so far by the patient will of course not be available if they have been recorded only on the missing FP25, possibly resulting in failure to collect due payment. And when the errant FP25 is later recovered, it must be fully updated with the details on the duplicate form.

A practice with fully computerised clinical records will therefore virtually grind to a halt whenever the system fails. This is bad enough when the 'downtime' is only temporary, due to a power cut, or a computer failure. But if a major hardware fault occurs, such as a headcrash, and a substantial proportion of the records are lost, on the very day when someone spills coffee over all the floppy disks containing the backup records, the consequences are too dire to dwell upon.

At this point, you may say 'I realise fully the dangers of giving up conventional written records, yet the advantages of having fully computerised records seem so great that I would be willing to maintain both manual and computer records together.' If you want peace of mind regarding the ability of your practice to go on functioning during computer downtime, yet want to be able to carry out epidemiological surveys or other investigations based on the analysis of clinical data, then this is the only course open, but it is a hard discipline to maintain two sets of records in the same state. Inevitably one version, ie either the FP25 or the computer record, will receive more attention than the other, and discrepancies will creep in over a short period of time. Also, none of the other benefits of computerised records, such as ease of

storage, retrieval, and manipulation, will be realised if the FP25 record still has to be retrieved as before.

There will no doubt come a time when computer storage methods are far more reliable and comprehensive than they are today. By that time, radiographs will be stored as digital images in the computer, and all correspondence will be in the form of electronic mail, so then there may perhaps be no need to keep our familiar FP25s. Until then, they will remain the medium of choice for the storage of treatment details, charting, and medical history, as well as enclosures such as radiographs and correspondence.

PRACTICE MANAGEMENT

In considering the general management and financial applications of computers within a dental practice, it is useful to emphasise the dental practitioner's status as an independent contractor, paid for the work he carries out according to itemised treatment fees, either NHS or private. It is assumed for the purposes of this discussion that this state of affairs will continue for the foresee able future without significant change.

The current cumbersome process of claiming payment for NHS treatment using FP17 forms must be at the top of the list of possible applications of computers for every dentist who treats patients under the NHS. Currently an FP17 form must be completed for each patient who has received treatment under the NHS, or for whom treatment requiring prior approval has been prescribed. This is then posted to the DEB at Eastbourne, where it is processed for payment or approval. Although some current practice computer systems assist in the preparation and printing of FP17 forms, it is generally accepted that the opportunities for real progress in this area lie in the various schemes for the electronic submission of estimates directly to the DEB. This subject is best discussed in the context of the relationship between the dentist and the DEB, therefore all aspects of how the computer has been and may in future be used to automate the preparation and transmission of NHS estimates will be discussed in the next chapter.

The FP17 form is a statutory document used for three

purposes: first, to record the contract between dentist and patient; second, to request prior approval for certain forms of treatment, and third, to claim fees from the NHS, in respect of treatment completed according to agreed scales.

Assuming that the FP17 as we know it will be around for some time to come, what are its disadvantages, and how can a computer within the practice alleviate the problems in its preparation? The principal problems associated with the FP17 from the practice's viewpoint (ie not taking processing at the DEB into consideration) are as follows:

1 Time consuming to prepare.

2 Printing of dentist's name, address and contract number using rubber stamps supplied by FPC is often not very legible.

3 Duplication of information – charting and treatment details are written twice – on both FP25 and FP17.

4 Errors can easily arise in transcription of information from FP25 to FP17.

5 Forms can be lost or mislaid, especially in the post.

Before considering the possible solutions to these problems, however, it is worth mentioning the points that paper FP17s have in their favour:

1 Low costs – FP17s and suitable envelopes are supplied free by FPCs, and postage is relatively inexpensive.

2 Legal requirements concerning the recording of the contract between patient and dentist, and the confirmation of the dentist that information on the FP17 is correct, are satisfied by means of the signatures of both patient and dentist on the form.

In 1983, the report entitled 'Computers in General Dental Practice', prepared by a tripartite working party consisting of representatives from the BDA, the DEB, and the DHSS, estimated that the average effort required each year to complete the FP17 claim forms for an average dentist in full time NHS practice was around 20 working days. Since then, the average

number of forms submitted per dentist has increased, although the forms have been redesigned and are slightly easier to complete. Although this task has traditionally been delegated to ancillary staff within the practice, nevertheless most dentists spend considerable amounts of their time checking and validating completed forms, since they are of course responsible for ensuring the accuracy of information on each form they sign.

Since all the information required for the completion of the FP17 is already present on the FP25, it follows that any system in which clinical records have been fully computerised will hold all of the information necessary to prepare FP17s, and some current systems are capable of formatting the information relating to the current course of treatment in a manner suitable for overprinting of a standard FP17 form. Given that the effort has been made to input treatment details into the computer for the purpose of updating clinical records, it would certainly seem sensible to make use of this data to prepare the estimate forms. However, there are, as always, further difficulties involved.

Completion of the average FP17 requires printing in a number of places on the form, and these are frequently scattered in such a way as to require considerable movement of the printer head and of the form in the printer feeder. This all takes time, with the result that even computer printing of an FP17 usually takes over a minute. Admittedly this compares well with the average four minutes cited in the Scicon report as being the average time taken for manual completion. However, in most commercial computer systems, the advantage in the computer printing of documents arises from its execution as a batch process, whereby the computer can be left to get on with printing a batch of forms without any intervention by the user. The idea of leaving the computer to print out FP17s unsupervised, perhaps even overnight, has considerable appeal. However, despite improvements in the consistency of printing of FP17s since the form was redesigned in 1985, there is still some variation between batches in the precise alignment of the printing on the form. So, even if your printer has an auto-feed device which ensures that the edge of each form will always be initially positioned in the same relationship to the printer head, there in no guarantee that the characters printed will appear in the correct boxes on the form.

Some FP17 form-printing systems have the capacity for adjustment of alignment to take account of this variation between FP17 batches. Although this refinement (if used in conjunction with a test facility so that for each new batch of forms received from the FPC, trial forms can be printed with successive adjustments until alignment is correct) will allow high-quality completion of FP17s, it would be highly inadvisable to leave a batch of forms in an auto-feeder to be printed unattended. Great care would be necessary to ensure that all the forms were placed in the feeder in the correct order, with the patient's signatures on the back of each form corresponding to the name on the record to be printed on it. If a form was wrongly placed in the batch, or if, as quite often occurs, the feeder fed two forms in together, on all the subsequent printed forms the signatures would not match up with the records! So if a printer is to be used to produce completed FP17s, forms must be fed in manually one at a time - a tedious business.

The 1983 report on *Computers in General Dental Practice* stated that about 7% of estimates contain requests for the prior approval of the DEB to treatment proposed. These are usually the most time consuming FP17s to complete and it is unlikely that a computer printing system will be of much assistance in the completion of Part 11, the section in which the necessary observations must be made. In any case, the form would have to be fed twice through the printer to achieve printing on both sides.

There seems little justification therefore for the use of the computer to complete FP17 claims at present, although it should be noted that all the stated objections relate to the problems associated with printing the FP17 form, which was not in any case designed for completion by computer. Once alternative methods of transmission of claims and prior approval requests have been established, the use of the computer in the preparation of such claims will be undeniable.

Before leaving the subject of computer printed FP17s, it has been suggested (Lynn 1987) that a certain amount of information could usefully be printed on the forms in advance, prior to their being signed by patients. If records containing patients' name, sex, date of birth, and address are already stored on the

computer, then this information for each patient due to attend on a given day, together with the dentist's name, address, and contract number, could be batch printed in advance, saving a certain amount of time and guaranteeing the clarity of the all-important contract number. Because such forms would not have been signed by the patient at the time of printing, errors in form feeding would be merely inconvenient, rather than catastrophic.

Fees accounts calculation and analysis

Treatment carried out under the terms of the NHS is remunerated on a fee per item of service basis and this is likely to continue for some time as the basis on which dentists are paid for most of their work, despite the various capitation schemes currently being evaluated. The *Statement of Dental Remuneration*, published annually, shows fees for all the different types of treatment that are subject to a fixed scale, ie all those not requiring prior approval, and for some of the less complex items requiring approval. The word 'treatment' here should of course be taken to include items relating to diagnosis and preventive therapy.

The calculation of patients' charges in respect of NHS treatment is still a time-consuming and error-prone process, despite the introduction in April 1988 of proportional charges, whereby the patient pays 75% of the dentist's fees for routine treatment, and fixed charges for dentures and bridges, the total charge for a course of treatment being subject to a maximum of £150.

Although this is a vast improvement on the previous highly complex system, the dentist or member of staff responsible for billing the patient still has to look up the fees relating to treatment, and fixed charges for dentures and bridges, the total charge for a course of treatment being subject to a maximum of £150.
calculations have to be done 'on the fly' which results in not infrequent errors; there are over 200 different items recorded in the schedule and no human being can reasonably expect to remember the fees for more than a few of the most commonly occurring items. A further problem arises when checking total

charges at the completion of a course of treatment; careful note must be taken of the date on which treatment commenced, because two different fee scales are often in operation concurrently where a new scale has recently been introduced.

Any computer system recording full clinical treatment details will be capable of calculating total fees due and the sum payable by the patient without the need for any duplication of input data. However, the usefulness of the computer for calculating NHS fees is so great that it is an application worth considering even if the details of treatment that will be required as input will form no part of the patient's record. Indeed, useful small systems, running on inexpensive portable computers, have been developed for this sole purpose.

A reasonable compromise for those who have no desire to store full clinical details with patient records in the computer system is to calculate the total fees due and the sum payable for each patient using a separate program, then subsequently input these totals into appropriate fields in the patient's computerised record. If fields storing the date on which the most recent estimate was sent to the DEB, and also whether or not the fee has yet been paid are also included, this will then provide ready access to information on which patients owe money, and which claims are currently outstanding.

The long delay between provision of NHS treatment and subsequent remuneration by the FPC can cause problems of cash flow. It is highly desirable for a dentist to know accurately how much money he is owed at any given time, both by individual patients and the DEB, in other words the accounts receivable. Since practice overheads are largely fixed, consisting mainly of salaries, rates, rental of premises, and investment in equipment, the accounts receivable is the only highly variable amount in the overall financial profile – the one that can make the difference between profit and loss. There is nothing the individual dentist can do to hasten the processing of his FP17 claims, apart from ensuring that they are completed accurately and legibly and despatched as soon as possible after treatment has been completed. So, if the computer system is to optimise the management of accounts receivable, we would expect the following services:

1 Identification of patients for whom a course of treatment has been completed, but full payment has not been received.

2 Identification of patients who have failed to return within a reasonable period of time for part or all of the treatment prescribed.

For each patient identified in one of the above categories, we wish to check the following:

a Whether patient has paid the appropriate patient's charge (NHS or private).

b In the case of NHS patients, whether an FP17 has been completed and submitted.

c If an FP17 has been submitted, whether payment for that treatment has appeared on a schedule.

3 Patient billing, by means of personalised letters with a message appropriate to the sum owed and the length of time overdue.

To provide these services, the following information needs to be known for each patient:

Date current course of treatment commenced

Date most recent course of treatment finished

Total cost of treatment provided in this course

Patient's charge for treatment provided in this course

Total payment made so far by patient for this course

Date estimate sent to DEB for this course

Payment made so far by FPC for this course

Since a patient can have a number of different courses of treatment concurrently in progress, the above fields might for example be contained within a new record type, called 'treatment course', occurrences of which are linked to a single patient record, in such a way that any number of treatment course records can point to a given patient record, and a single patient record can point to any number of treatment course records, but

no two patient records can point to the same treatment course record, nor can a single treatment course record point to two patient records. Furthermore, each occurrence of a treatment course must point to an occurrence of patient, but patient record occurrences can exist quite happily without being necessarily linked to any treatment course occurrences; the patient does not have to be undergoing a current course of treatment, but any existing course of treatment cannot exist in isolation; it must relate to a particular patient. We say that the patient record is the owner of treatment course record, which in turn is a member record of patient. The relationship of these two record types is shown in Figure 3.1.

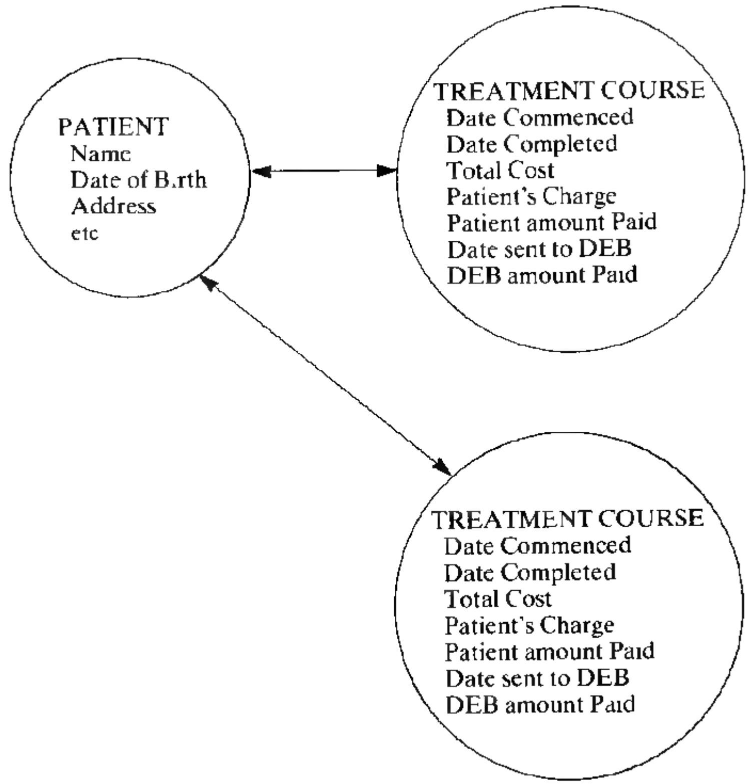

Figure 3.1 Relationship Between PATIENT and TREATMENT COURSE Records.

Identification of all unfinished or unpaid courses of treatment can now be performed by a simple program; here is an outline of how the logic of this program might look:

1 Open the file of treatment course records

2 Read the first record

3 If Date completed = more than one months ago
and Patient amount paid < Patient charge
then add record to Debtors list

4 If Date completed = empty [ie none recorded]
then add record to list of Unfinished treatment records

5 If treatment was carried out privately then go to step 9

6 If Date completed = non empty [ie treatment complete]
and Date sent to DEB = empty
then add record to list of FP17s to be completed

7 If Date sent to DEB = more than three months ago
and DEB amount paid < (Total cost – Patient charge)
then add record to list of DEB late payments

8 If (Patient amount paid + DEB amount paid) = total cost
and FP17 has been sent to DEB [don't allow 'backpocketing'!]
then delete record from file

9 If treatment was carried out privately
and patient amount paid = Patient charge
then delete record from file

10 Read the next record

11 If end of file reached, then finish, else go to step 3.

The above program is run against the file of treatment course records at regular intervals to produce the following lists (as new files):

— unfinished treatment records;

— FP17s to be completed;

— debtors list;

— DEB late payments list.

Unfinished treatment records

It is worth checking this list to identify any courses of treatment that have been in progress for an unduly long time; if there turns out to be no good reason for this, since the treatment does not involve orthodontics or any other procedures usually regarded as being long term in their execution, and the patient has no outstanding appointments, the decision can then be made whether the FP17 should be sent in as 'failed to return', or whether attempts should be made to contact him. If the latter course of action is taken, the word-processing function of the computer can be used to prepare a suitably worded letter.

FP17s to be completed

A common cause of delay in submission of FP17 forms is the accidental misfiling of the associated FP25 back into the 'dead' filing cabinet while the record is still current. In a fully manual system such errors will only be uncovered by going through all the FP25s in the practice; many practices undertake this laborious task at intervals. It is generally agreed that the amount of money the average practice has tied up in FP17s that should have been sent off ages ago is more than sufficient justification for this time-consuming process.

Checking of the treatment course records by computer will quickly identify records which have a valid completion date but no recorded date of submission. These are the ones for which an FP17 must be completed and sent as soon as possible.

Debtors list

The program described above will retrieve records where there is a sum owed by the patient in respect of treatment that was completed more than a month ago. How this data is used further will depend on the type of practice involved. The management of patient billing is of considerable importance in private practices, where the custom is to send an account when the treatment has been completed. In contrast, most NHS practices require payment either before or at the time of provision of treatment.

Having obtained the debtors list, it can now be processed by a

further program, along the following lines:

1 Open the file of Debtor records [which are treatment course records]

2 Read the first record

3 Let amount owing = (Patient's charge – Patient amount paid)

4 If amount owing < £1 then go to step 9 [ie forget if less than £1]

5 If today's date – Date completed = 1–2 months then send 1month letter

6 If today's date Date completed = 2–3 months then send 2month letter

7 If today's date – Date completed = 3–4 months then send 3month letter

8 If today's date – Date completed > 4 months then send final letter

9 Read the next record

10 If end of file reached then finish, else go to step 3.

Word processing is fundamental to the above processes, both for the creation of suitably worded form letters, and also to ensure that appropriate names, addresses, amounts of money due, and length of time overdue are included. The wording of the various form letters is obviously dependent on the nature of the practice's clientele, but the longer the time that payment is overdue, the more strongly worded should be the letter. So '1month letter' would be simply a statement of account, '2month letter' a reminder that payment is overdue, '3month letter' a further reminder, perhaps adding that two previous accounts have been sent and appealing to the patient's honour in settling his bills, and 'final letter' might contain wording to the effect that further steps will be taken to recover the debt if it is not settled promptly.

Having printed a 'delinquency report' each month, showing which patients owe money and the amount involved, it may be

desirable to contact serious cases by telephone or even to call round personally. How much more useful the report would be, then, if the report included telephone numbers and addresses of the patients involved and also the date and amount of their last payment, in case there has been some misunderstanding about whether they have paid. These little 'extras', which can make life so much easier, are too much to expect from a staff doing everything manually, but are usually simple to add to the functions of a computer system, provided it has been designed correctly.

DEB late payments list

If any courses of treatment are identified for which FP17s have been submitted to the DEB more than three months previously without full payment of the state's contribution to the fees for that course having appeared on any subsequent monthly schedule, the matter can be taken further by writing to the DEB to confirm whether the FP17s involved were actually received at Eastbourne. If an envelope containing the forms has become lost in the post, this will at least show which patients they relate to so that new FP17s can be prepared after those patients have been contacted.

The number of FP17 forms processed at the DEB runs to over 33 million a year, and it would be surprising if some errors did not arise during processing on this scale, especially as all data from the FP17s is currently input by fallible human beings. Therefore it may be that certain items from a small number of FP17s never make it into the DEB computer, with the result that the eventual sum shown on the monthly schedule as being payable by the FPC does not tally with the amount recorded on the practice computer. Identification of such cases is performed rapidly and efficiently using the computer.

The use of the computer to issue printed receipts should be mentioned here. Every time the patient makes a payment, the amount paid has to be added to the Patient amount paid field in the treatment course record; this action can be used to trigger the printing of a receipt for the appropriate amount, with details of the amount still owed, if any. Details of each payment can be

added to a Patient payments file, analysis of which will reveal how much money has been taken over a period of time. The issuing of computer-printed receipts can be of considerable help in ensuring that all money taken from patients is accounted for at the end of each working day. However, since issue of receipts occurs throughout the day at irregular intervals, a separate printer may be needed for this purpose; patients cannot be expected to wait for their receipt while the printer is preparing a batch of recall letters. The same of course applies to appointments slips.

In the system outlined above, records relating to courses of treatment are only maintained until the treatment has been completed, and the full contributions have been paid by both the patient and the DEB; they are then deleted, but only if there is confirmation that, in the case of NHS patients, an FP17 form has been sent off to the DEB, thus avoiding any possible accusations of 'backpocketing'.

The continual references to 'courses of treatment' may be offending the sensibilities of many readers, who would point out that there is a significant move away from viewing dentists as providers of discrete courses of treatment, consisting of items with a high operational element, towards continuous programmes of general dental care with little or even no operative content, being concerned with disease prevention, counselling and prophylaxis. The terminology used in the discussion so far has of course been constrained to deal with the current situation as regards NHS dental treatment which, despite the plans for 'continuing care' in the proposed new contract, is still very much geared towards thinking in terms of courses of treatment. However, many dentists are being attracted towards the various private capitation schemes, in which the dentist usually sets fee rates for individual patients which will cover the cost of all dental care over a given period, and administration of fee payments is carried out by a central agency. This book is hardly a suitable place for discussion of the merits of such schemes from a clinical viewpoint, but from a financial viewpoint they have the advantages of helping to eliminate bad debts, and ensuring predictability of income. There are of course further benefits from the administrative viewpoint, since the time consuming calculation of patients' NHS charges and completion of FP17s are eliminated.

With a computer system it is practicable for the dentist to establish and administer his own private capitation scheme for his patients, without involving a third party. The capitation fee is usually payable at fixed intervals, for example of 3, 6, or 12 months. So a suitable capitation record would have a one-to-one link with a patient record, and fields indicating the following:

1 Months of the year (as numbers from 1–12) in which capitation payments are due

2 Patient's premium (may vary for different patients)

3 Amount outstanding

4 A 'late payment flag' which can be set to indicate that a payment is overdue.

An outline program for preparing capitation fee accounts might look like this:

1 Open the file of Capitation records

2 Read the first record

3 If Amount outstanding > 0 then set late payment flag

4 If number of current month appears in list of months in which accounts are to be sent then add Patient's premium to Amount outstanding

5 If amount outstanding > 0 then
If late payment flag set then send strongly worded letter else send statement letter

6 Read the next record

7 If end of file reached then finish, else go to step 3.

Further elaborations allowing more forceful letters to be created as debts age can be made along lines shown in the earlier program.

Before leaving the subject of accounts receivable, it is worth mentioning a further advantage of computerisation; the provision of a comprehensive audit trail. A computer will not eliminate errors by practice staff. In either a manual or an automated system, occasional errors and omissions will arise in the entering of

charges and payments. In a manual office, however, the most expedient solution to an error is to change it, ie to reach for the rubber or the bottle of correction fluid, and re-enter the correct information without bothering to record that the error occurred. This increases the potential for sloppiness or even dishonesty and it is often difficult, after the fact, to see what caused the mistake. A well-designed computer system should not allow errors to be corrected without recording the reason for the error and the amount of money involved. Often, the system will not allow the error to be simply changed; a new entry might have to be made as an adjustment or reversal. Such adjustments can be emphasised in reports by placing them automatically in a column by themselves; this can reveal much about the number and nature of mistakes made by each individual user of the system.

Practice accounts payable

Opinions differ as to the usefulness of a computerised system for management of practice accounts payable. Commercial business packages dealing with Purchase and General ledgers are widely available and are sufficiently general-purpose to be usable in dental practices if required. Postings can be made to such headings as:

Wages

PAYE

Petty Cash

Car Expenses

Laundry

Supplies

Rent/Rates

Equipment Depreciation

Miscellaneous

The production of neatly printed accounts can help to save accountancy fees. It is worth seeking the advice of your accountant as to which commercial software packages are best for preparing accounts for submission to him for audit.

Payroll

This application was one of the first commercial uses of computers. However, the average dental practice does not employ enough staff to make computerisation of wages and PAYE worthwhile; it is generally reckoned to be appropriate only in businesses with more than ten employees.

The automation of payroll calculation is however very straightforward, and a variety of inexpensive software packages are available to run on many microcomputers. If you have a real aversion to using the PAYE and NI tables supplied by the Inland Revenue, and you already have a computer, it might be worth the effort and expense.

Stock control

This is another controversial application. The usefulness of a computerised stock control system is largely dependent upon the size of the practice and the type of dentistry practised therein. However, it is worth quoting from the Scicon report:

> "Most dentists claimed – some with triumph that their method of stock control comprised peering into the stock cupboards to see if they ought to order more consumable supplies. However, in no case did a dentist have any real idea as to the value of his consumable stock. Some dentists hazarded a guess but did not demur when we suggested that the true value might be even three times the value they had guessed."

The average dental practice commonly holds between 200 and 400 different items of stock, many of which are highly expensive, notably filling materials. Moreover, dental materials are said to account for 15% of gross annual practice expenditure. A computerised stock control system can provide much useful information, including the amounts of different materials used and their relative costs over a given period of time, and comparison of the different amounts used by different dentists in a multi-surgery practice. There is also considerable advantage to be gained from taking advantage of special offer bulk purchases of certain items, and a new development gaining in popularity is

the establishment of dental 'bulletin boards' – central databases containing up-to-the-minute information on current bargain offers, which can be accessed remotely using the dentist's own computer.

Another development along similar lines is the facility offered by some dental suppliers for ordering of goods by computer using the Prestel viewdata service. This will be discussed more fully in a later chapter, but as far as stock is concerned, a sophisticated scanning device, probably based on the conventional bar-coding system, detecting automatically any stock in need of reordering, and placing the order via Prestel or some similar service, may be the basis of stock management in the dental practice of the future. Like payroll, stock control is, in its own right, certainly no justification for buying a computer; but once a practice has bought one it may well be worth using it for these marginal applications.

A simple stock control system can be easily developed using a spreadsheet program. This is a generic name for a popular type of commercial software package for manipulating rows and columns of figures. Most rely on a grid or matrix format in which data in the form of labels, eg Amount of Item X held; figures, eg 100g; or formulae to perform the necessary calculations, can be entered directly into individual cells, or placed there automatically as the result of calculations performed on the contents of other cells.

The grid might look like this:

DESCRIPTION	MAX STOCK	MIN STOCK	CURRENT STOCK	COST (£)
Amalgam alloy (kg)	2	0 5	1.5	120
Prophy paste (jars)	3	1	2	5
Rubber dam (boxes)	3	1	1	10
Needles (x100)	10	1	2	5
Matrix bands (doz)	5	1	3	1

Further columns could include DATE LAST ORDERED, and amounts of each item used in different surgeries of the practice. The system is updated every time stock is received from suppliers or withdrawn from the stock cupboard for use in the surgery.

At regular intervals, the program prints a list of all the items which are at or near the minimum stock level, and also includes details of the cost of each item to be ordered, with a total figure for the required quantities of each item.

A further advantage can be gained by using one of the many integrated packages available – these combine the spreadsheet with a business graphics utility which allows information from the spreadsheet to be displayed in diagrammatic form (for example, as line or bar graphs, or pie charts). These visual presentations help in identifying at a glance the major sources of expenditure on consumables.

4 Computing and the DEB

BACKGROUND

No dentist who treats significant numbers of patients under the terms of the NHS would dispute that the automation of NHS fee claim processing, together with the elimination of the paper FP17 form, is one of the prime targets we would wish to achieve through computerisation. In order to fully appreciate the issues involved in the processing of NHS fee claims, it is necessary to know a little about the workings of the Dental Estimates Board (DEB).

The DEB, as is well known by all dentists, was set up in 1948 at the inception of the NHS. Its functions are as follows:

1 To process and consider estimates submitted for prior approval or for approval of payment; the board may give or withhold approval as it thinks fit.

2 To ensure that treatment proposed or provided is proper and necessary.

3 To authorise fees for payment to dentists and to prepare schedules in respect of these payments for Family Practitioner Committees (FPCs).

4 To detect and bring to the notice of FPCs any apparent failure of dentists to comply with their terms of service.

5 To bring to the notice of the DHSS any cases which may involve the provision of excessive dental treatment

6 To provide statistics to the Dental Rates Study Group, on the basis of which the fees for items of treatment are fixed.

7 To submit an annual report to the Secretary of State.

The level of processing activity at the DEB has from its inception been very high. Even in its first year of operation, over 3 million estimates were considered; by 1985 this had risen to over 33 million per year.

An average of 700,000 paper FP17 estimates arrive at Eastbourne every week, via the postal service. Once removed from their envelopes, they are sorted and vetted to establish that dentist and patient details are legible. Often the dentist's name is not clear, possibly due to a worn rubber stamp, so a Dentist Index has to be consulted and the relevant details added or rendered legible. The reverse side of the estimate is checked to ensure that relevant exemption details have been provided. Following these checks, the estimate will progress in one of several directions: for payment – to the data preparation section; for approval – to the prior approval sections; payment estimates with details of treatment or observations in part 11 – to the payment sections; for orthodontic treatment – to the orthodontic section; and there are various other sections to deal with more complex enquiries.

The volume of the processing performed by the DEB made it a prime candidate for automation, and punched-card equipment had been in use there for a considerable period before the first electronic computer was installed. This was a second-hand ICL mainframe with paper-tape storage, that had been previously installed in DHSS offices at Newcastle; it was installed on an experimental basis in 1973, and two years later, following the success of this trial, a new ICL 1904 mainframe was commissioned.

The details relating to straightforward payment estimates are keyed into disk files by a team of 180 data preparation operators, who are given the estimates in batches of 200. Data is transferred from the disk files onto magnetic tape, from which it can be read by the mainframe computer. This intermediate stage is necessary because the data preparation equipment is not compatible with the mainframe.

Once in the mainframe computer, the estimate may be rejected for a number of reasons, although in 1985, 96% of estimates

proceeded without further query. Reasons for rejection include incorrect date of birth related to treatment (eg five year olds don't usually have wisdom teeth removed!), invalid contract numbers, or treatment completed without the necessary prior approval. Validation of details with regard to the dental history of a patient, for example to reject estimates for repeat treatment done within a certain time period, cannot be done at this stage at present, being carried out at the time of scheduling instead.

The computer carries out the routine tasks of validation, sorting, comparison with historical records, and comparison with an index of dentists, completing its task by pricing the items of treatment provided, calculating the total amount due for each estimate, and printing payment schedules for use by the FPC; line printers used for printing the schedules can operate at 1500 lines per minute.

In the ten years up to 1985 the number of estimate forms received at Eastbourne rose from 27 to 33 million. By this time, the computer system was beginning to show its age. Considerable improvements in computer hardware had taken place by the mid 1980s, and it was realised that it would be more cost effective to buy a new computer rather than go on supporting an outdated system which was becoming increasingly expensive to maintain. Therefore the decision was taken to install a new ICL series 39 mainframe, with vastly superior processing capabilities.

Despite the success of the original computer system, it had two features which had always been recognised as limiting its use. These were as follows:

1 Estimate forms were sorted under dentist.

2 Histories of treatment of individual teeth were not kept.

These limitations, resulting from cost restrictions and the need for rapid implementation which did not allow sufficient time for extensive trials, meant that the data held by the DEB computer could not be used to estimate the lifespan of individual treatments, such as dentures, crowns, fillings, etc, nor for the purpose of forensic identification. The improved capacity of the new system meant that these highly desirable features could become a reality.

The direct submission of estimates by electronic means, from dental practices to the DEB computer, has long been identified as a solution to the problems associated with the FP17 forms. The Scicon report stated "...for the use of computers in practices to be fully effective, mechanisation of FP17 completion must be regarded as essential." Moreover it was realised that the mechanisation of estimates would allow a reduction in the number of data preparation staff at the DEB, thus saving money which could be used for other purposes, such as the employment of more professional advisers, to improve the level of service.

The report gave technical details of a number of options for computerising aspects of the claims system, and went on to note a number of considerations which required resolution before any useful progress could be made in this field. It recommended that these matters be discussed further in consultation with the Health Departments, and that a limited pilot study be implemented to test the effectiveness of the various options for processing claims.

APPROACHES TO COMPUTERISATION OF CLAIMS

In order of complexity, the following are the alternative approaches to the computerisation of claims suggested by the Scicon report:

- overprinting of FP17s in the surgery;
- using optical character recognition to read printed forms;
- replacement of the form by tape or disk;
- direct electronic transmission of claims.

Overprinting of FP17s in the surgery

The simplest method suggested was to use a printer in the surgery to insert entries in the appropriate boxes on the forms. At the time of the Scicon report, the old style large FP17 was still in use, on which the alignment of printed matter was so inconsistent that it was impossible to guarantee correct registration of the computer-printed entries. The report recommended the redesigning of this form, and an A4-sized replacement was introduced in 1985. Despite considerable improvements in the consistency of

the print on the new style forms, there are still variations between batches. Other disadvantages of this method were discussed at length in Chapter 3.

Furthermore, this approach had little to offer as far as the DEB itself was concerned; apart from improving the legibility of forms, it would not diminish the amount of work required in entering the data to the computer.

Using Optical Character Recognition to read printed forms

This alternative was simply an extension to the previous one – FP17s would be overprinted in the surgery and posted to Eastbourne in the usual manner. At Eastbourne there would be a number of Optical Character Recognition (OCR) readers which would scan the incoming FP17s and record their data directly in the DEB computer.

The OCR method was the subject of a limited trial at the Scottish DEB, but the results were unsuccessful because the entries were handwritten onto the form. Variations in handwriting were such that OCR equipment could not cope effectively. Despite improvements in technology since then, the use of OCR techniques to interpret handwritten information reliably and quickly is some way off. The reason for this is not difficult to appreciate after seeing a selection of the barely legible forms that arrive daily at Eastbourne; many are impossible for humans to read, let alone a computer.

Since OCR is not practicable without computer printed forms, the difficulties involved in printing forms in the surgery effectively rule out this option.

Replacement of the form by tape or disk

In this scheme, a program would be supplied to each practice on a master disk. This would be run on the practice computer and would display on the screen a form similar to an FP17. Data would be entered and the program would arrange this input data into a suitable format. The program would be rerun for each new estimate. Once per week, or at specified times, the computer would dump the accumulated claims information onto a floppy

disk which would then be posted to Eastbourne. The dentist could sign on the disk envelope, and patients' signatures could be made on another form which would be enclosed with the disk. If required, hard copy of all the claims data on a disk could be printed off at the surgery and kept as a record.

Since the average number of FP17 claims made per dentist per month is around 200, and the average number of characters (ie numbers or letters) on each form is about 55, according to the Scicon Report, a single 360 KB capacity floppy disk would be able to hold details of all the claims an average dentist would make over two three years. Disks would be read at the DEB by disk readers which would send data to microcomputers for initial processing. These microcomputers would have a link to the mainframe, through which they would transmit suitably formatted data.

The main difficulties associated with this system were due to the shortcomings of floppy disks; they are easily degraded and it was thought that a high proportion would be received in an unreadable condition. Furthermore, because of the high throughput of disks at Eastbourne, wear and tear on the disk readers would be severe so that maintenance requirements would be considerable.

Direct electronic transmission of claims

The Scicon report recognised that at the time of its compilation (1981), the technology necessary for electronic claims transmission was not yet sufficiently developed to make such a scheme practicable, but it provided some guidelines as to what would be feasible in the future. It suggested that data should be captured in the surgery in the manner described in the third option above, then at the end of each working day, or at times prescribed by the DEB, the data would be transmitted to Eastbourne via the telephone line. Two methods of transmission were suggested. The first involved the use of teletex. This is an internationally standardised text communications service for word processors and electronic typewriters – a high-speed replacement for the old-fashioned telex service. (Teletex should not be confused with teletext – this is the use of spare lines in broadcast television to

transmit magazines of text information such as CEEFAX and ORACLE.)

The other suggested means of transmission was via a Packet Switched Network. This is worth considering in detail because it is the basis for the trial service implemented in 1987 and it will doubtless be used in the definitive scheme when it commences. At this point it is necessary to gain some insight into the subject of computer-to-computer communications. Let us begin with some history.

The essential technique of sending data along wires has a history of 150 years, and some of the common terminology of modern data transmission goes right back to the initial experiments. The earliest form of telegraphy used the remote actuation of electrical relays to leave marks on a strip of paper. Letters of the alphabet were coded in patterns of 'mark' and 'space', corresponding to binary conditions of 1 and 0 respectively. The first reliable machine for sending letters and figures dates from 1840; the direct successor of that machine, using remarkably unchanged electromechanical technology and a 5-bit alphabetic code, is still widely used today in the familiar telex machine. Marks and spaces have been replaced by holes punched in paper tape: large holes for mark, smaller ones for space. Synchronisation between sending and receiving stations is achieved by beginning each letter with a 'start' bit (a space) and concluding it with a 'stop' bit (mark). In effect, therefore, each letter requires the transmission of seven bits.

Until 1876, telegraph companies enjoyed a monopoly on the use of electrical impulses to transmit data between distant sites. In that year, however, Alexander Graham Bell demonstrated that electrical signals could be used to transmit voice messages along telephone lines, and so a second data communications channel was established. The first linkage of computing and communication devices occurred in 1940, when George Stibliz used telegraph lines to send data from Dartmouth College, New Hampshire, to a Bell Laboratories calculator in New York City. But it was not until the late 1950s that the convergence of the computing and telecommunications industries began in earnest. An early large project was the SABRE passenger reservation

system developed by American Airlines and IBM, in which hundreds of scattered terminals were linked to a central processing centre. Since then communications usage has grown steadily, and most large computers communicate with a number of outlying terminals. As more personal computers are attached to communications networks, and as more of the equipment in an organisational setting is linked together by data communications, the distinction between computing and communications will become even more blurred.

The speed of data transmission is measured in baud – the baud is the level of signal changes in the line per second. Therefore it can be regarded as equivalent to the number of bits of data (zeroes or ones) transmitted per second. Typical speeds achieved in a telex line are 50–75 baud, which means, since seven bits are sent per character, that about 7 10 characters per second will appear at the other end. Anyone who has watched a teleprinter chattering away in a hotel foyer will testify to their impressive lack of speed.

Voice grade telephone circuits are able to carry data at much higher speeds. For computer communication, 'marks' and 'spaces' can be represented by different audio tones, rather than by different voltage conditions. The original 5-bit code has been replaced by the standard 7-bit ASCII code which allows the full range of characters. Start and stop bits have been retained to provide synchronisation between the processors at either end of the line. A further bit, known as the parity bit, is added to reduce errors in transmission; all the bits in the character are added together, and the result determines the value of the parity bit according to whether it is odd (parity 0) or even (parity 1). So 10 bits are used to represent one character. This is known as asynchronous transmission; transmitting and receiving devices are not synchronised to send and receive data at fixed intervals – instead, data is transmitted as and when available, and received in the same manner.

In a voice grade circuit, the use of different pairs of tones will allow several different data streams to be carried at a given instant, and these need not be going in the same direction. The use of the terms transmitter and receiver is therefore inappropriate, and one should talk in terms of originate and answer instead.

The fastest reliable transmission speed using an ordinary voice-grade telephone line is generally regarded as 1200 baud. Beyond this, noise on the line, due to the switching circuits at the intermediate exchanges (which are still mostly electromechanical), and poor cabling, make accurate transmission difficult. At higher speeds it becomes increasingly important to use transmission protocols that include sophisticated error correction, with extra parity checking. So the benefit gained from the extra transmission speed may be cancelled out by the greater number of bits needed to be sent for each character.

Because transmission of data along a telephone line is in analogue form, using continuously variable frequencies, and data within computer systems exists in digital form, a modem is required at either end of a data communications link. Modems handle the conversion of binary digital data (in the form of electronic pulses) into modulated wave forms (modulation), and its reconversion once transmitted (demodulation). They do not initiate any data themselves, though they may handle ancillary tasks such as automatically dialling a remote computer terminal.

Let us return to the subject of transmitting estimates to the DEB from dental practices. It is reasonable to assume that the only practical way the data can leave the surgery is via the British Telecom telephone line – the expense of installing a new dedicated cable linking the DEB to every practice in the country would be rather excessive! So, estimate data is going to start its journey to the DEB at the rate of 1200 baud, or 120 characters per second. There are about 15,000 dentists in England and Wales who accept patients under the NHS scheme. And at any one time, dozens of them could be attempting to send estimates to the DEB. Dentists don't usually send off a whole month's estimates in one envelope – they usually send smaller numbers at more frequent intervals. Since communication via the telephone line requires both parties to be on-line throughout transmission, if estimates were to travel the whole way to the DEB in this manner, dozens of new lines would need to be installed there. And at each of these lines there would need to be a modem and a link to the DEB computer.

There is a further important point. Considering the speed with which the DEB computer can process information, it would seem rather wasteful to present data to it at the rate of only 120 characters per second – it simply is not making anything like the full use of the resources available. To sum up, data communication using telephone lines, while convenient to perform, acts as a severe 'bottleneck' in the process of getting information from one computer to another, and is simply not adequate for networks involving large-scale processing.

The relatively slow speed of transmission along telephone lines is a result of the need, in such lines, to be able to distinguish frequencies within the entire audio spectrum between 100 Hz and 3000 Hz. Moreover, the technology needs to be sensitive to a wide range of amplitude: speech is made up of pitch and associated loudness. But simple digits are all that is needed to be transmitted between computers and it does not matter whether they are signified by audio tones, radio frequency waves, voltage conditions or even light pulses, so long as there is circuitry at either end which can encode and decode

With a purely digital transmission, routeing of a 'call' does not have to be physical; the communication path does not have to be kept open throughout transmission of the message. Instead, a message can be broken down into blocks or packets of data, each block bearing an electronic label of its origin and destination address, these addresses being read in digital exchanges using microprocessor chips, rather than electromechanical devices, to switch data from one communication line to another. Two benefits are thus obtained simultaneously: the valuable physical path (ie the cable) is only in use when data is actually being transmitted, and is not in use during 'silence'; secondly, switching can be much faster and more reliable. These ideas form the basis of packet-switched networks; digital networks capable of sending data at the rate of 48,000 bits per second.

Packets of data in a single transmission stream may all follow the same physical path or may use alternative routes, depending on levels of congestion in various parts of the network. The packets comprising one transmission may well be interleaved with packets from many other transmissions, but the originating and

receiving computers see none of this. At the receiving end, the various packets are stripped of their routeing information, and reassembled in the correct order before presentation to the VDU or applications program.

Before it can be sent through a packet-switched network, the estimate data has to be assembled into packets of suitable size, which then have to be given an address, that of the DEB. This is done by a device known as a PAD (packet assembler/disassembler) which sits on the network, and is accessed via the standard telephone line. The PAD is dialled up from the surgery, using a modem. On connection, the PAD takes over control of the dentist's terminal; prompts are sent to the screen to request details of the data to be transmitted, including the address of the receiver. It then returns control to the dentist's computer, with a message confirming how many packets have been sent, and where to.

Packet-switched networks conform to an international standard known as X25, which takes care of any inherent incompatibility between different computer architectures and operating systems, allowing any type of machine to talk to any other on the network. This means that dentists will in most cases be able to use their existing computers to access the network, without the need to invest in new equipment other than a suitable modem. A further advantage of using packet-switched networks is that unlike the telephone service, all charges are independent of the distance of transmission, being dependent solely upon the number of packets sent.

THE TRIPARTITE WORKING GROUP

In response to the Scicon report, a tripartite working group was established, with representatives from the DHSS, the BDA and the DEB. In its 1983 report *Computers in General Dental Practice*, the working party confirmed the view of the Scicon report that computerisation offered the means to alleviate many of the administrative problems faced by dental practices, stating: "...it would be surprising if there were not a significant number of dentists whose practices could be made more cost-effective by some computerisation."

However, as far as elimination of written FP17s was concerned, the report adopted a very cautious attitude. Considerable emphasis was given to the statutory and financial implications of the various options for the automation of claims.

Statutory implications

The most important is the requirement for dentists' and patients' signatures on estimate forms. The requirement stems not from the primary legislation governing the general dental services, but from the secondary legislation, ie Regulations. Technically there was no obstacle to amending these as required in order to accommodate a computerised system. But there were both legal and quasi-legal issues involved:

1. Signatures are not essential to the making of a contract between dentist and patient but they have considerable evidential value; for example, in resolving disputes about whether treatment has been carried out under the NHS or privately.
2. There is doubt as to whether a photocopy or facsimile of a signature would satisfy legal requirements for signature.
3. While signatures do serve a useful purpose, there is no fundamental requirement that they should appear on the FP17 form; it would be possible to amend regulations to allow development of a new system based on a separate register of signatures.
4. It might be sufficient for a dentist to submit a batch of estimates with a single signature by himself to cover all of them. However, if all the information was transferred to tape or disk, the question of how a dentist would certify that the data was correct needs careful consideration. There could be errors, accidental or deliberate, in transferring the information and a single signature to cover a tape or disk would be evidentially weak. Moreover, a personal identification code for a tape or disk would be no guarantee against fraud as such codes are not foolproof.

The working party considered it essential for there to be some evidence of contract between patient and dentist for NHS

treatment, and also for the retention, in some form, of the various patient undertakings, and certification by both patient and dentist that treatment had been completed.

One possibility considered, with regard to the implementation of direct electronic transmission of claims data, was the removal of any requirement for either the patient or the dentist to sign the actual estimate form. The dentist's certification would then be provided to the DEB on a separate form, payment being dependent upon the processing of these forms by the DEB. An identification code on each form would correspond with the same code appearing on the computerised claim. As for the necessary patient signatures, they would be written on an expanded version of the present dental acceptance form. This would incorporate the patient's undertaking to pay the necessary charges as well as any claim to exemption or remission, and a copy could be kept by the dentist. However, this approach would be associated with several difficulties:

- — extra work for the DEB, caused by the need to reconcile computerised estimates and dentists' signatures received separately;
- — the fact that the dentist, in submitting his claim for payment, would in effect be claiming exemption or remission from charges on behalf of his patient, something for which the patient at present takes sole responsibility;
- — and, perhaps most importantly, the evidential problems which might arise in the absence of patient signatures on claims for payment.

Another, less radical approach considered was for the patient to sign the dental acceptance card at the beginning of a course of treatment, as evidence of acceptance for NHS treatment; for the estimate forms to be computer printed, and for patient and dentist to sign them at the end of treatment. This would not result in any reduction of the workload at the DEB, however.

Financial implications

The working party stressed the importance of a coherent strategy for the computerisation of dental practices, in the interests of

public spending. Dentists buying computers for their practices are able to offset the expenditure against taxable income; this is counted as a practice expense and therefore reimbursed to the profession as a whole through the remuneration system. Furthermore, unless a significant proportion of dentists decided to computerise their practices, it would be difficult to justify the investment necessary at the DEB to make the central computer compatible with the practice computers. It was accepted that computerisation should at no time be forced upon dentists; some would inevitably choose not to computerise and any changes made centrally would need to cater for both manual and computerised access to the payment system. In the words of the report, '. . .parallel paper systems for all aspects of general dental practice will be required for the foreseeable future.'

WORKING PARTY RECOMMENDATIONS

In the light of all the above difficulties, the report recommended a pilot study of the use of computers in dental practice, which would focus on developing software to computerise the present payment and clinical records systems. This was to run for two–three years, and was to involve up to 100 volunteer practices. A steering group was to be established to oversee this pilot study.

Dentists participating in the trial would meet 50% of their hardware costs and the remaining costs would be met by central government. But the entire cost of developing suitable software was to be borne by government.

The report did not state explicitly how this software was to be developed. The very cautious tone of the entire contents, however, seemed to suggest that software should be produced entirely within the DHSS, presumably for security reasons. At the time the working party was preparing the report, considerable publicity was being given by the media to the new cult of 'hacking' – unauthorised use of central computers by access from remote terminals; and to general problems of security in computer systems. The members were very concerned about the scope for abuse in a computerised claims system; hence the lack of encouragement for private software companies (many of whom were in league with practising dentists) to participate in the project.

Another factor was the desirability of any computerised payments system to be capable of being easily updated, to take account of changes in fee scales and patients' charges. This raised the question of which were the most appropriate agencies to be involved in the writing of software. It was pointed out that the confidentiality surrounding any changes in patients' charges, for reasons of parliamentary privilege, would mean that there would normally be no longer than three weeks in which to update software.

This restriction, and the suggested length of the pilot study, resulted in the report finding little approval either from interested dentists or from the computer industry. Although, following the report, an announcement had been made that £1.9 million would be allocated to the pilot scheme, it never took place in its proposed form and funding was withdrawn pending further consultations.

The next report to consider computerisation in dental practices, produced in 1984 by the management consultancy firm of Arthur Andersen, was entitled *A Study of Family Practitioner Services Administration and the Use of Computers*. This report dealt with many other matters besides the General Dental Service, but identified the dental payments system as one of four major administrative systems forming the core of the overall strategy for computerisation of the FPS.

The Andersen report advocated the updating of the DEB computer to allow improvements to the processing of claims, and that provision should be made for some dentists to submit claims electronically, but did not concern itself with the technical details of how this should be achieved. A network within the DEB for electronic transmission of data would also be implemented, so that information could be circulated more efficiently between the clerical staff and the dental advisers. Transmission of payment schedules from the DEB to the FPC would also be electronic. It was suggested that these changes at the DEB would be self-financing, allowing staff levels to be reduced from 1450 to 600 by the mid 1990s. The report also recommended three further areas where future technological improvements might have an impact:

1 Gradual replacement of the dental advisory staff by 'expert' computer systems.

2 Electronic transmission of radiographs to and within the DEB in a digitised form.

3 The use of holograms for transmitting and storing images of dental models.

The report also raised the possibility of patients retaining their own dental records, in the form of a computer-readable plastic card, similar to a credit card. In some countries, 'smart cards', containing their own processor and memory, are already being used to store personal bank account details and medical records. As many patients change dentists frequently, this would be a convenient way of ensuring that their medical and dental histories are available to whoever treats them.

Further important recommendations concerning the computer system at the DEB were made in 1986 by the Schanschieff Committee of Enquiry into Unnecessary Dental Treatment. These were as follows:

1 A statistician should be seconded from the DHSS to the DEB to aid in the development of computer programs to provide statistics necessary to identify dentists who provide unnecessary treatment.

2 The routine collection and use of patient-linked data within each FPC, and across FPC boundaries, should be an early priority for the new DEB computer system.

3 Treatment records should be stored in the DEB computer system for a minimum of three years.

In August 1986, the DHSS agreed once more to make funds available for the long-awaited pilot study to link practices electronically with the DEB computer. Two documents issued in October of that year, entitled *The Patient Record System* and *A Pilot Trial of the Electronic Data Transmission of Dental Claims* containing specifications determined by the DHSS, were issued to various software houses who were already involved in the dental market. These gave full details of the formats in which electronic estimate data would be accepted by the DEB computer, and also

of how computer systems within a dental practice should store the primary patient record, the FP25, in such a way as to allow maximum integration between it and the estimate record, with data in a common form.

Four software suppliers were initially selected to take part in the trial, which commenced in June 1987; three actually participated. The first stage of the trial involved 18 dentists working in eight different practices, all of which were already computerised to a significant extent. Modems were supplied free of charge. During this stage, conventional written FP17 estimate forms had to be submitted to the DEB in parallel with the electronic estimates, and only these written forms were actually processed for payment. A new Minstrel 4 microcomputer was installed at the DEB to decode the electronic claims received. During the initial stage, the decoded claims were simply printed out and reconciled against the written FP17s received. This was necessary, because an acceptably high level of accuracy had to be demonstrated before the electronic claims could actually be accepted into the main computer directly, and paper FP17 forms dispensed with.

The pilot trial made history by being the very first public or private sector scheme in the UK which involved the electronic claiming of money belonging to another person or institution (in this case, the dentist claims money from the state). Contrast this with, say, using a bank automated teller machine – in this case, the user is simply using a computer terminal to claim money which already belongs to him. Similarly, in a computerised point-of-sale system, the customer has to authorise the debit of funds from his own credit account – the retailer cannot authorise a debit to be made from the customer. Therefore, it was imperative that a clear and precise audit trail be established in the pilot trial. The entire series of transactions, beginning with the patient requesting NHS treatment and ending with the dentist being paid, had to be capable of being traced. Furthermore, the security of the system had to be established.

An evaluation of the pilot trial was carried out by management consultants Touche Ross, who reported in December 1987. The trial was considered a success. It was established beyond doubt

that the electronic transmission of claims could be achieved, and that electronically-generated claims contained fewer errors on average than traditional manually prepared estimates. However, the eight practices taking part in the pilot trial were not a representative sample; all their staff had already had considerable experience of using computers, so extrapolation of the results over all practices would be an exercise of limited validity.

For the second stage of the trial, due to commence in 1988, the NHS (General Dental Services) Regulations 1973 have been amended, enabling those dentists submitting electronic claims to dispense with sending paper form FP17s as well. Up to 200 dentists are expected to take part in this stage.

The method of transmission actually used in the trials, which will almost certainly be adopted for use in the definitive system, is the FASTRAK network. This is a high-speed data transmission network, operated by a subsidiary of the Midland Bank, which conforms to the X25 protocol for packet-switched networks, the use of which was envisaged as long ago as 1981 in the Scicon Report. A popular program called KERMIT which supports asynchronous data communications between any different types of computers, is used to transmit data from the surgery to a local PAD; from there transmission is via the FASTRAK network. On dial up, the dentist's VDU will look like a terminal to the DEB computer, and will be presented with a prompt to type in a password for security Once successfully logged on, a simple menu follows, allowing the dentist to send the previously prepared claims data to the DEB, or to access a mailbox, a private store for messages from the DEB to that dentist, which would be used to store any DEB response data, eg notices concerning prior approval. When the scheme is working fully, the transmitted data will be accepted into the DEB's database stored in the main computer. Any problems will be reported to the dentist concerned, and a message will confirm that data has been received. The dentist will then 'log off' and this will automatically cut off his computer from the network, returning it to the control of its own operating system.

The difficulties arising from the need for patients' and dentists' signatures have been resolved in the pilot trial by introducing two new paper forms, one of which is the equivalent of parts 13 and 14 of the FP17. The patient signs this as usual, then the form is retained by the practice, and stored within the FP25 envelope. Every month, the dentist has to sign a summary form, printed out in the practice, which records brief details of all estimates sent during the previous month. This is then posted to the DEB, but will only be used in the event of a query; the processing of electronically submitted estimates will not have to wait until the relevant summary form has been received.

Another difficulty which had to be overcome through changes in legislation was that the DEB needs to have the right to refuse electronically-transmitted estimates if there is a risk of incorrect or corrupt data interfering with its mainframe system, once there is a direct link into this system. The DEB has no right to refuse to accept paper FP17s, no matter how illegible they may be; but electronic estimates must conform to the published specifications in order to be acceptable.

All practices wishing to submit electronic estimates, other than those participating in stage 1 of the pilot scheme, will have to supply their own equipment. Assuming that most are eventually going to buy a computer anyway to perform other administrative tasks, the only extra expense will be the modem. The cost of the modems used in the pilot study was about £450, but it is likely that dentists will be able to buy adequate modems at lower cost, probably around £200.

The three companies which provided software for the initial pilot study are all suppliers of comprehensive dental practice management systems. However, when the scheme is fully operational, a number of dentists will no doubt wish to submit electronic claims without incurring the expense and effort required for full practice computerisation. Therefore individuals will be permitted to use their own software, provided it is approved by the DHSS; a fee will be charged for evaluating such software This approach is very different from that envisaged by the tripartite working party; it encourages private companies to develop software to a common standard while avoiding the creation of a monopoly. Copyright will remain the property of the software developers.

Eventually, details of payments may be sent electronically from the DEB to FPCs, who will in turn cause the correct funds to be transferred directly into dentists' bank accounts. This could result in the dentist being paid for his work almost immediately after making a claim, although for the time being, claims for an individual dentist will only be processed once per month, as they are at present.

Already, the database stored in the DEB computer has been expanded to include details of payments over the last 24 months, from a previous period of 13 months. It has also become possible to cross-reference items on estimates from different dentists working in the same practice. These improvements, and other procedures for monitoring claims to prevent and detect fraud and abuse, will take full account of the recommendations of the Schanschieff committee. The increased undertaking of this work by the computer will free staff resources, allowing more attention to be given to answering specific enquiries and attending to the more serious cases of suspected abuse.

5 Computer System Selection and Implementation

GENERAL

Having performed a full analysis of his practice and determined which areas to computerise, the dentist will be in a position to investigate the various systems on offer and to choose a combination of hardware and software. This is probably the most difficult task in the whole process of computerisation, because of the ever widening variety of products available and the often misleading claims for which the computer industry is justly renowned.

If a comprehensive dental practice management system, with recalls, appointments, clinical record keeping, accounting, stock control and all the other major clerical activities included, is being considered, then the choice of hardware should be made subordinate to the selection of the right software. These integrated sets of programs are usually referred to as 'turnkey' systems – the user does not have to load them all separately; all he has to do is switch on. With a turnkey system, it does not matter if it uses an obscure hardware and operating system combination – there should be no need to buy any further software so the fact that there is little software generally available for that machine should not be a problem.

On the other hand, if a more cautious approach is taken to computerisation, perhaps starting with recalls and word processing facilities only, the choice of the hardware becomes much more important, since no doubt the user will want to add further applications as he grows increasingly confident with the computer. It is frustrating at this stage to find that he has bought a

computer which very few software writers are catering for: he may be unable to get the application he wants to run on his computer, or alternatively what software is available may be of low quality or excessively priced, due to a lack of competition in that sector of the market.

While it would seem rational to judge a microcomputer system on the basis of its memory size, the speed and power of its processor, and the general quality of construction, it is often the case that the most technically advanced machines turn out not to be wise purchases. In the microcomputer world, compatibility is all-important. The more machines that use a particular architecture (ie the same processor) and operating system, the more companies will develop software for that combination. This has three effects: the amount of different applications catered for increases, costs come down, and standards go up due to increased competition.

IBM PC AND CLONES

The classic example of the virtues of compatibility is that of the IBM PC and its many imitators or 'clones'. The basic and most popular version uses the Intel 8086 processor, although a more advanced model, the PC AT, has an improved processor, the 80286, which runs about three times as fast. The IBM compatible machines can run a variety of different operating systems, the most popular being MS-DOS. Within this range, prices vary widely, according to the quality of the machines, and the number and type of disk storage devices provided, but a machine of reasonable quality, such as the Amstrad PC1640 with 640 KB RAM, a 20 MB hard disk and a single floppy drive can be had for under £1000. There are plenty of machines that are more technically advanced than the IBM PC and its clones – but none have achieved anything like the same degree of acceptance. Despite IBM's introduction of a new range of microcomputers in 1987, called PS/2, with an entirely new operating system, OS/2, there is no doubt that the 8086 and 80286 family of IBM compatibles will be around for a long time to come, and MS-DOS will continue to be a popular operating system catered for by many software authors.

The major limitation of MS-DOS is that it is not multi-tasking; it cannot run concurrent applications. So, in a single terminal system, the user would have to shut down one application, for example, printing recall letters, before switching to another such as finding a patient record. However, this problem can be overcome by using a multi-tasking operating system such as Concurrent-DOS which will run quite satisfactorily on IBM compatibles. This enables the user to switch between concurrent applications at will, using windows on the screen.

The dentist wishing to buy a microcomputer to run a few basic applications would therefore find a PC clone to be a safe bet. But he should certainly look at the other machines on offer. The benefits of having a hard disk are so great that it is really not worth buying a computer without one; the difference in cost between a floppy disk drive version and a hard disk/floppy disk version is far less significant than the difference in their relative usefulness. Among those alternatives to IBM compatibles which have a reasonable amount of software written for them are the Apple Macintosh and the Atari ST, both of which use the advanced Motorola 68000 series of processors. The BBC microcomputer, for so long the favourite of dental computer buffs, was never really powerful enough to run serious applications other than word processing and simple recalls, and must now be regarded as an outmoded machine; it was, after all, introduced way back in 1981, which in computing terms was a very long time ago. But its manufacturers, Acorn, introduced a new machine, the Archimedes, in late 1987. Given the enthusiasm with which this machine has been greeted by the computing press, and the excellent reputation of its predecessor, this could well be the microcomputer of the future.

SOFTWARE AND RELIABILITY

Compared with the state of the market only a few years ago, the popular business microcomputers of today represent excellent value for money, and whichever machine the dentist chooses, he will no doubt find a considerable amount of good general-purpose software available, such as word processing and accounting packages. As far as specific dental software is concerned, until recently most software companies concentrated on developing turnkey systems in which hardware and software were sold as a

package. There is a considerable movement towards developing modular software; specific applications packages which can be bought separately, allowing the dentist to select his own computer. This has the advantage that the hardware can be bought from a local supplier, resulting in easier maintenance.

The standards of microcomputers in the late 1980s are so high compared to machines on offer only five years ago that it will be some time before software is developed that can actually make optimal utilisation of today's hardware. Computers nowadays are very reliable and there really is little chance of any of their electronic components failing. Therefore the frequently encountered attitude that "...it's not worth buying a computer because next week's model will render it obsolete" is simply no longer valid; today's computer hardware is sufficiently powerful and reliable to be useful in dental practices, and no matter what developments lie ahead, a computer purchased today will go on performing its tasks indefinitely.

The only parts of a computer system that are, unfortunately, still prone to failure are those which have moving parts, namely the disk drives (especially hard disks) and printers. Although all microcomputers come with at least a one-year guarantee as standard, if there is a failure and the machine has to be sent to a service depot, the practice may have to do without it for a number of weeks. This time can be reduced by having an on-site hardware maintenance contract which can usually be arranged through a local dealer. If the computer is only being used for recalls and other non-time-critical applications, downtime is not such a serious problem; if, however, the appointments and clinical records are all on-line, it may be necessary to have a backup computer as a spare.

Although the standard and performance of microcomputer hardware is now very high, the same cannot always be said for software. There are a number of good reasons for this and, in order to evaluate dental software, it is worth knowing about how the industry has developed, in order to gain an insight into the reasons why some systems have not lived up to expectations.

DENTISTS AS A VERTICAL MARKET

With the advent of the microcomputer in the late 1970s, it

became clear that, as computers became accessible to an increasing range of businesses, inevitably there would follow the development of 'vertical markets' for software; in other words, a company that developed a suite of programs for, say, a dairy farmer would then be able to sell the same package to all the other dairy farmers, who, being in the same business, would presumably have similar management requirements, and thus would be able to use the same software package.

It seemed certain that a well defined vertical market for dental practice management software would emerge, and since general dental practice was considered a relatively high profit enterprise compared to other small businesses, it was clear that considerable gains would be made by any firm which captured a share of this lucrative market. This encouraged a number of software companies, large and small, to develop systems in league with interested dentists.

For any new technology to become successfully developed and applied, a number of 'pioneers' are needed; those who are sufficiently interested in the potential offered by a new advance, and in the kudos associated with it, to be willing to incur high expenditure and put up with the inevitable 'teething problems'. It is well known that members of the dental profession tend to be interested in innovation and are generally 'gadget-conscious', so there was no difficulty in recruiting dentists willing to cooperate in the design and development of these systems.

Although one might have expected the first commercial dental practice systems to be fairly rudimentary, perhaps performing just one simple basic function such as management of a recall list, instead most of these early systems were ambitious in the functions they performed. There were two main reasons for this. Firstly, in order to justify the then very high cost of the hardware, it seemed desirable to make the computer do as much as possible. Secondly, the highly structured system of notation used to record charting of dentitions seemed to many computer experts to lend itself to representation by computer.

One of the vogue phrases used by the computer industry during the 1970s and early 1980s to describe the working environment of the future, where computers would handle all mundane clerical

tasks, described the 'paperless office'. Happily this absurd term has fallen out of favour, as it has been realised that this is not necessarily an appropriate goal, even if feasible; an image on a VDU screen is often not an adequate substitute for a hard copy. But when the early dental practice systems were being designed, the elimination of bulky filing cabinets full of FP25s seemed to be a prerequisite. These systems were highly complex, and, although some enjoyed a degree of success in the specific practice around which they were built, they tended to be too inflexible for use in other practices.

An unfortunate but inevitable result of the competition between different companies to produce commercially viable systems was that there was little opportunity for participating practices to learn from each others' mistakes and to benefit from shared knowledge. Therefore there was a good deal of 'reinventing the wheel', and much wasted effort in solving problems which someone else had already solved. The most disappointing aspect of this was that new systems were generally no better than earlier ones. A frequently encountered scenario is where a dentist, having seen available systems and been unimpressed by them, decides to develop his own package in league with a software company. The result is usually just another version of some existing package, but tailored strictly to his own needs, thus leading to its rejection by other dentists in just the same way as he has rejected other systems, and so the cycle continues. The similarities are enormous, the differences only slight, the result being a recurring invention of the same wheel. No careful analysis of the differences has been made, nor any attempt to produce a flexible package which might allow for such variations, although the number of dentists with experience in the field is quite adequate to provide this knowledge, were a thorough survey to be undertaken.

SYSTEM FAILINGS

Furthermore, the vagaries of human nature tend to ensure that the failings of these systems receive far less publicity than the advantages. Nobody who has spent many thousands of pounds on a computer system, or anything else for that matter, finds it easy to admit publicly that he has wasted his money, thus reports of

unsatisfactory systems are extremely rare. Two examples in the literature are worth mentioning. The Americans, as always, were far ahead of us in adopting computers, and a considerable number of them had computerised their practices by the mid 1970s. Beyer (1973) reported the results of a new practice computer billing system in glowing terms. Rates of collection were improved, costs were reduced, and more time was spent with patients. But two years later, a further report (Beyer 1975) revealed that the practice had gone bankrupt. Bills had apparently been addressed wrongly, and some were never sent. Obviously this is an extreme case from the early days of practice computing, but many other failures on a lesser scale have gone unreported since then.

SYSTEM DEVELOPMENT

An unfortunate fact of life is that good software is extremely costly to develop. Development does not finish when the last line of code has been written; thorough testing is vital. But testing is extremely time consuming, and the temptation is always to market the product as soon as possible and fix any bugs later, particularly in small software companies unable to meet large development costs Also, the provision of good documentation, in the form of a user manual, is vitally important yet almost never satisfactorily achieved. A user manual should never be written by the programmer; he knows all about the intricacies of his program and will probably assume that everyone else does too. Yet to employ the services of a professional technical author is beyond the scope of most small software houses. Hence the appallingly low standard of so many user manuals.

Hopefully, the initiative of the DHSS in issuing specifications for the systems for the electronic submission of claims and the storage of patient records should lead to common standards in the dental software industry; there may henceforth be less time spent on reinventing the wheel, and more effort devoted to testing and documentation of products.

PRODUCT EVALUATION

Given that the above rather pessimistic overview of the dental

software industry has not put off the reader entirely from buying its products, how should he evaluate them? In answering this question, it is probably most useful to consider turnkey systems, since the expense of these systems makes careful evaluation essential prior to purchase, whereas individual modules bought to run on an already purchased computer will probably be relatively inexpensive, in the region of £50–£200, and obtained through mail order. In the case of these packages, prior testing will usually not possible, though some companies offer a money-back deal by which the program disks can be returned within a certain time limit if the purchaser is not satisfied.

In contrast, the turnkey system, costing upwards of £2000, represents a major capital outlay. Evaluation must therefore be taken seriously. The first step, after study of the glossy brochures, is to find out as much as possible about the company concerned Firstly, how long has it been trading? If less than two years, its products must be regarded as unproven. Even more important is the size of the company. An organisation consisting of a dentist and one or two professional programmers may well be capable of developing brilliant software. But they will not have the resources to provide after sales support. Would anyone buy Ford motor cars if there was only one garage in the whole country that could service them?

The necessity for support grows exponentially as systems get bigger and more complex. As far as hardware is concerned, the problem is not severe – most popular computers can be serviced by local agents acting as third parties. But software can only be supported by the company that developed it. Software support, or maintenance, consists of two activities vital to the integrity of the system. Firstly, some bugs will inevitably require fixing; these are faults in the logic of the software which cause programs to react incorrectly to certain inputs. Although these inputs may themselves be incorrect, they are bound to occur eventually that is when bugs show themselves. The effect of such a bug may be minor, or occasionally catastrophic, causing the program to 'crash', ie halt suddenly, with the possible loss of all data currently in RAM.

Any relatively untried software will contain bugs, and some

will be severe enough to require fixing. The other maintenance activity is that of updating the system to take account of changes in the outside world. For example, any software used in the calculation of NHS fee payments will need updating yearly to take account of revised fee scales. If the supplier of the software goes out of business, it may well be impossible (and very dangerous) for the dentist to attempt to alter the program himself. To sum up, support is vital throughout the entire life of the computer system. It is salutary to note that 80% of computer programmers working in large commercial systems spend all or most of their time maintaining existing programs, rather than actually developing new ones. Of course, software support does not have to be carried out 'on site'; new versions of programs can be posted or even sent electronically using a modem, and many problems can be solved over the telephone. But a certain amount of training will be necessary before the practice staff can use the new system, and this of course should be carried out in the practice. So, any serious software company supplying comprehensive dental turnkey systems should have more than just a handful of staff.

Because software development and testing takes a long time, beware of any claims that a software module is 'nearly ready'. A golden rule is 'if you can't see it being satisfactorily demonstrated, assume it doesn't exist'. The somewhat cynical term 'vapourware' has been coined to describe products which are always 'nearly ready' but never actually get delivered; the computer industry has a tendency to produce a considerable amount of this.

Obviously the prospective purchaser will want to see the system 'up and running' before making any firm decision to buy. The only satisfactory environment in which to judge a dental system is a working dental practice. A demonstration at the software company's office is probably not worth the effort of attending, because it will inevitably be restricted to showing the software in its best light, strenuously avoiding any shortcomings that are likely to become apparent in a real working environment. It will be impossible to get any real idea of how fast the system will perform in a practice. Patient record retrieval, for example, may be accomplished within three seconds if there are only a

handful of records to choose from in a test database set up for the demonstration. But the same operation in the same system might take much longer when a large number of records, say 5000, are to be chosen from.

Any supplier of turnkey systems must be able to provide demonstrations at a reference site; a practice in which the product has been installed, with a realistic number of records stored in the database. Only then can its performance be judged. Speed of record access is an essential consideration if real-time activities such as appointment booking or receipt printing are to be engaged in. It is not so important in applications which are going to run as batch processes, eg printing recall letters, which can be left to run overnight if necessary.

When visiting the reference site, effort should be made to discuss the system with all those who use it, not just the owner of the practice. If a supplier is unable to demonstrate at a reference site, he should be prepared to let the dentist use the system in his own practice for a free trial period.

Having thus selected a number of viable suppliers and made arrangements to visit the reference practices, the following criteria should be used in judging the systems on trial:

- manual and documentation;
- the man-machine interface;
- on-screen help facilities;
- hard copy output.

Manual and documentation

Strong though the temptation may be to rush straight to the keyboard and start typing, a good deal of information can be gained by looking at the manual. Does it look professional? Is it properly printed? Does it contain spelling mistakes? These factors may appear to have nothing whatever to do with the quality of the software, but in fact they speak volumes about the company and its attitudes. If a company has produced a professional, well printed manual with no spelling mistakes, then they have obviously taken time over it, and this is a good

indication that they have also taken due time in developing and testing their product. Testing and debugging should account for around 50% of the development cost of a software project (Brooks 1975).

Conversely, a brief, photocopied manual, full of misspellings and obviously written as an afterthought does not augur well for the quality of the software it purports to document. It is not uncommon to see misspellings even in the dialogue on the computer screen, and this really is not good enough. Even the most basic word processors nowadays have a spelling check feature, so there can be no excuse for failing to use it. Of course, even a professional looking manual may not necessarily be comprehensible; it is well worth taking time to read through the first few pages to see if it makes sense!

The man-machine interface

The man-machine interface (MMI), alternatively known as the human computer interface (HCI), is the term used to describe the dialogue between the user and the computer, and is a much studied field. It is clear that computers are not as easy to use as they should be; many people still have an aversion to them. In years to come, everybody will need to interact with computers, hence the importance of finding ways to make them as easy to operate, or as user-friendly, as possible; in fact they should be enjoyable to use – just as a modern, well-engineered car is enjoyable to drive – as well as performing a useful function.

No doubt the time will come when computers will respond to spoken instructions, but until then, users will have to communicate with the computer via the keyboard and screen. With this in mind it is worth testing the keyboard thoroughly to ensure it has a good 'feel' – keys should have a positive feel when depressed and should be reasonably quiet: there is a very wide variation in the quality of keyboards and it is worth trying out a few to appreciate the difference between them.

If none of the staff who are to use the computer have any experience of typing, it may be worth purchasing a typing tutor program. These are available for all makes of computer and are inexpensive (around £20). They provide an interactive environ-

ment for the user to develop and improve his or her keyboard skills and are usually very 'user-friendly', thus providing an ideal introduction to the computer for those who have never used one before.

The problems inherent in communication using a keyboard have already been discussed, but in many types of query, the use of a mouse or other pointing device in association with the keyboard makes for much easier input, provided the software has been designed to work on a menu basis. New or inexperienced computer users will usually find WIMPS (Windows, Icons, Mice and Pointers) software very user friendly, but computer buffs may find the associated desktop metaphor, in which various icons representing filing cabinets, calculators and other office items are selected by using an on-screen pointer, rather frustrating and patronising, since it effectively shields them from the workings of the operating system. A nice feature of WIMPS software is that it does not force the user to use a mouse; the pointer can be moved equally well with the four cursor (arrow) keys.

Whether a mouse is used or not, menus are a good way of presenting the user with choices at each stage of the dialogue. This is preferable to a 'query language' where the user tells the computer exactly what he wants. Although the query language approach is more powerful, allowing a very wide range of ad hoc enquiries to be made, it involves learning a new language, whereas selection from a menu requires no programming at all.

Screen layout should be clear and should correspond as far as possible to equivalent paper forms, if any. Flashing or inverse video highlighting of part of the screen is acceptable in some cases to draw attention to medical problems, or an overdue bill, but should not be overdone as too much grabbing of the user's attention can be very tiring. Where permanent data has to be input, for example to create a record for a new patient, a screen format should be used in which the user enters data appropriate to the panel currently identified by the cursor, then the cursor moves to the next panel automatically, and so on until the entire screen form is complete. This ensures that the user is prompted to supply all the necessary data.

A well-designed interface should make maximum use of

default values. For example, when completing a screen-based form with the details for a new patient record, it saves time if the field corresponding to the town where the patient lives can assign the most likely value, ie the town where the surgery is, automatically unless an alternative is specified. So for example, if the surgery was in London, the address field for a new patient would have 'London' assigned to it automatically if the receptionist simply pressed the return key instead of entering an alternative.

Similarly, the system should 'know' that the first letter of every name, street, or town must start with a capital, and ensure that even if the user forgets to press the shift key, initials will automatically capitalise. This may seem very trivial but it is remarkable just how much easier it makes the life of the receptionist – for example, since she doesn't need to use the shift key, she could be typing in data with one hand while holding the telephone in her other hand. In a busy practice, such considerations can make a huge difference.

One of the fundamental principles of MMI design accepts that human users, being fallible, are liable to enter incorrect data, and tries to minimise the opportunity for them to do so. A good example of this is the menu; the user is presented with a list of options, usually making his selection by pressing an appropriate key, for example:

CHOOSE ONE OF THE FOLLOWING:

Create a new record .... a

Update an existing record .... b

Delete a record c

Leave this menu .... d

The user would press a, b, c, or d, according to what he wished to achieve. The system should ignore any other key pressed accidentally, and should report, in plain English, that a wrong key has been pressed, perhaps with a discrete warning 'beep', and request input to be re-entered. It should not crash on receiving incorrect or unexpected input – the user is, after all, only human and is bound to make occasional errors in input.

The capacity of a computer system to cope with input errors is referred to as its robustness. The robustness of every screen dialogue encountered in the system should be tested by deliberately entering as many mistakes as possible in entering data. For instance, if a letter is asked for, enter a number and vice versa. Check for case sensitivity also – upper and lower case letters should be equally acceptable to the system.

The possibility exists for an even more sinister type of user error: where the user selects an option that does appear on the menu, but is not the one he meant to select – this can have truly devastating results. Suppose for example that a dentist, having just bought his new system, has begun to create his patient records file. He has spent the whole of his day off, typing details from FP25s into the computer. At the end of the day, he has typed in 200 records, and is quite pleased with his efforts – there are only 4800 left to type in! He leaves the record-entry screen, to be confronted with a new menu which looks like this:

CHOOSE ONE OF THE FOLLOWING:

Delete the file........... .... a

Save the file ....b

Append the file to existing records file..............................c

At this stage a slight hiccup in the learning curve occurs. The user confidently types 'save', ignoring the injunction to press a, b, or c (which was in any case never stated explicitly). The computer treats 'save' as four separate letters. It ignores the 's', as it has been told to, since that letter does not appear among the valid choices for that menu. Next it encounters an 'a'. This is of course a valid choice, and it tells the machine to do exactly the reverse of what the user intended! The result is that a whole day's work is lost in an instant. However ridiculous this example may seem, it can and does happen. This sort of problem can only be avoided by the computer issuing copious messages giving the user as much information as possible about what the system is about to do, before it does it, especially in the case of deletion of records or files, which is usually irreversible. Whenever the user selects from a menu an option to delete file xxx, another message should appear saying 'Are you sure you want to delete file xxx' or words

to that effect, giving him a chance to change his mind.

Output to the printer should also be checked for robustness. Test this by requesting the computer to print out a fairly long file, such as a list of all patients' names, ensuring that the printer only contains a few sheets of paper. Observe what happens when the printer runs out of paper. If it goes on printing onto thin air, or the program crashes, then the system is not sufficiently robust, and in a real life situation this could cause loss of data. All programs yielding hard copy output should detect paper runout, and should pause the printer until further paper has been loaded.

On-screen help facilities

A well-designed system should provide as much help to the inexperienced user as possible, and a good way of achieving this is to have pop-up help screens which appear when a certain reserved key (usually one of the function keys) is pressed, and contain hints on how to proceed from the point at which the key was pressed. For example, the help screen might give a more detailed explanation of the options summarised in a menu screen.

Hard copy output

Having exploded the rather inane myth of the paperless practice and accepted that we still need to produce hard copy appointment slips, receipts, recall letters, and day lists, to name just a few, it is important to see how well these are produced, and how easy they are to use. The use of window envelopes can save the time and expense of printing separate address labels, so is a highly desirable feature. Look at samples of all the different documents the system is going to create, and ensure that, if the layout is not to your liking, it can be changed easily.

After selecting a system which performs all the required functions, is supplied by a viable company, and appears to be of a suitable quality, the financial aspects can be considered. As with all dental equipment, there are various ways of purchasing a computer system, all with different tax implications. Leasing or even rental schemes may be preferable to outright purchase, and it is best to seek the advice of an accountant to ensure that the correct decision is reached.

Other considerations

Before purchase, the following additional details should be ascertained:

1 Terms of hardware guarantee (should be at least one year free).

2 Cost of on-site hardware maintenance – essential if the system is to provide vital functions such as appointment booking.

3 If on-site maintenance is required, how long will engineers take to arrive at a callout?

4 Cost of software maintenance including telephone support, and all necessary updates when fee scales are revised, etc.

5 Installation charges and time taken to install system.

6 Training costs. A full day's training should be provided free of charge.

7 Insurance. Hardware should be insured against theft or damage, to the value of its replacement cost, terms of indemnity being similar to those for other items of practice equipment. It will probably not be possible to insure against loss of vital data arising from defects in the software, however – hence the importance of keeping backup copies!

Check whether peripheral items and disk drives are included or have to be purchased separately. Items which will also be required, and must be budgeted for, are as follows:

1 Printer cables.

2 Printer paper, and special slips for receipts, recalls, and appointments.

3 Supply of blank disks, and suitable disk storage box.

4 Modem for linking to DEB computer or other computers.

5 Mouse (if sold as optional extra, well worth considering).

It is also worth investing in one or two user guides dedicated to the particular microcomputer you have purchased. There are

plenty of titles for all the popular makes and many are aimed at absolute beginners, often being much easier to understand than the official manual which comes with the computer. Your dealer should be able to advise on this matter.

INSTALLATION

After purchasing the system, the next step is of course installation. This is nowhere near the problem it used to be even a few years ago. Some of the early dental practice systems ran on minicomputers, which, besides requiring considerable space, usually needed installation by specialist engineers, and often required an air-conditioned environment. Microcomputers of a few years ago were far less robust than they are today, and hard disks in particular needed very careful handling and siting. Printers were far noisier and often required special sound-deadening housings to be built around them. Furthermore, the components of early systems were a good deal less physically integrated, and required expert assembly.

This situation has changed markedly. Microcomputers today need very little installation; it is usually a matter of taking a VDU, a system unit (containing the processor, memory, disk drives and hard disk) and the keyboard out of three separate boxes and plugging them together. If a multi-user system or network is to be installed, a cable will have to be run between the various terminals and this is best left to the supplier. But installation of a single microcomputer can usually be done by the purchaser.

It is worth taking a note of the size of the 'footprint' of the computer system unit, ie the area which it will occupy on the desk surface, prior to installation, so that suitable space can be reserved for each terminal. If installing a mouse, ensure there will be at least a square foot of the desk surface left clear, over which the mouse can be moved. In choosing a position for the terminal or terminals, extremes of temperature should be avoided, and the surface chosen should be solid and free from vibration as this can upset the hard disk mechanism. Also it should be kept well away from any areas where liquids are in use, and this includes drinks! If coffee is accidentally spilt into the keyboard or system unit it

will almost inevitably cause a system failure. Unfortunately, the full effect may be even greater, since such a catastrophe may cause the processor to send out random signals, possibly corrupting records stored on the hard disk.

In deciding the location of the terminals, consideration must be given to lighting; VDUs should be shielded from harsh lighting which causes glare, making the screen difficult to read. Prolonged use of a terminal can be very tiring, so the keyboard and screen must be positioned at a suitable height to allow the operator to sit comfortably. If a terminal is to be sited in a surgery, it will presumably be used to display clinical records, so it must be in a position easily viewed by the dentist sitting in his usual operating position, and it must be sufficiently close for him to read easily. This raises the question of who will input charting details. The normal practice is for the dental surgery assistant (dsa) to enter charting details on the FP25. If she is to enter such data into the computer, she will either need her own separate terminal, or alternatively the VDU can be mounted on a swing arm so that it can be moved between dentist and dsa. The ergonomic implications of such an arrangement are considerable so, if a terminal is to be placed in a surgery, specialist planning advice should be sought.

At this point, another important consideration arises; that of hygiene. If either the dentist, hygienist or dsa are to enter any data to a terminal in the surgery, they will of course have to wash their hands before and after using the keyboard. Although various protective keyboard covers are available, there is bound to be a risk of debris falling in the many traps between the keys. And, being quite delicate devices, keyboards cannot be cleaned or scrubbed like other work surfaces. This would seem to be yet another contraindication to the use of terminals within a surgery – the sterility of the keyboard cannot be guaranteed.

There is no evidence that VDUs emit hazardous radiation or are likely to have any other sinister effects on the health of users, and the practice staff should be reassured concerning this matter. The only hazards to health likely to occur are a result of bad posture; these can of course be avoided by ensuring that the keyboard and screen are at a height suitable for comfortable working.

Software is usually supplied on floppy disks and will require installing on the hard disk if present. In a turnkey system, this should be done by the supplier, since the setting up of a number of interdependent programs on a hard disk is time consuming and complex. However the user should find it simple to install modular packages himself and full instructions for doing this should be stated clearly in the manual.

Advice should be sought from the supplier on whether a mains supply filter is advisable to protect the computer from interference from very short high voltage 'spikes' which are sometimes superimposed on the mains supply when some other electrical device nearby is switched on or off. If these spikes find their way into the logic circuit of the processor, they may persuade it that it has just read a 'one' from memory, rather than a 'zero', with disastrous results.

CREATING THE PATIENT DATABASE

Once the system is 'up and running', the patient record files have to be created before it can perform any useful tasks, and this will probably take several weeks. The strategy adopted for building the database will vary according to the size of the practice (ie the number of patients), the applications to be performed by the computer system, and the number of staff available to perform the necessary data entry. In an established practice, it is unlikely that time or resources will permit all the necessary details to be entered in one go, and since recalls will almost certainly be among the applications performed by the system, priority should be given to entering details of those patients who are to be recalled for regular examinations. In a large practice, however, even entering only the basic registration details of the regular patients can take a long time, particularly if the available staff are not experienced typists.

Some practices have been known to take on extra temporary staff to enter the existing records into the computer, but this raises several practical difficulties. In a single terminal system, nobody else will be able to use the computer for any other task, such as word processing or fee calculation, while data entry is taking place. Furthermore, space is usually limited in the area

round the reception terminal, and there often is simply not room for extra staff to work in. A better solution may be to use an outside data entry agency. Record cards are sent off to the agency in batches, and staff at the agency key the details on to floppy disks, which are later copied to the hard disk in the practice computer. Of course, the practice has to do without each batch of FP25s for a day or so while they are at the agency but, with appropriate scheduling, this method would allow all the data from a large practice with 15,000 records to be transferred to the computer in as little as two weeks (Kemp-Davies, 1987).

If clinical records are to be stored in the system, it will probably be appropriate to abbreviate the details on the existing FP25. But the decision as to what is essential information to be included on the computer record, and what is non-essential, should not be left to the ancillary staff – hence a considerable amount of work for the clinician.

PARALLEL RUNNING

Computerisation inevitably entails a certain amount of change in working practices, and human nature tends to resist change. The longer the practice has been established, the more difficult it will be to reorganise its administrative functions around the computer. Therefore a reasonable period of time must be allowed for adjustment to the new methods involved. In practice this means, with a multi-function turnkey system, that it is best to introduce the applications one at a time, allowing staff to become familiar with each one before moving on to the next. Non-critical applications such as recalls should be introduced before essential functions such as appointment booking. Furthermore, the manual system should be maintained as usual, running parallel with the computer system, until all problems with the new system have been solved and staff have become proficient in its use.

If, after considering all the objections so far raised, the practice still wants to eliminate paper FP25s or the written appointment book, this should not be done until the computer system has been proved over a period of at least one month, during which time FP25s should continue to be updated and the appointment book maintained. To return from a fully computerised system to a

manual system, in the event of later dissatisfaction, will be far harder than it was to computerise in the first place, as some practices have already found.

An obvious problem with parallel running is the dramatic increase in the workload. All work must be performed twice, the old way and the new. And, because the new method of working is unfamiliar, the most confusing and error-prone time in implementation occurs during the early stage of parallel running. This is another powerful argument in favour of introducing applications one at a time, and parallel-running each one.

ACCEPTABILITY TO PATIENTS AND STAFF

At the time of the Scicon report in 1981, the microcomputer was still something of a novelty, and the general public was far less familiar with computers than it is today. The report found it necessary to warn dentists contemplating computerisation that the use of a computer could be seen by some patients as depersonalising their relationship with the dentist. This was thought to be a particular problem in rural areas with relatively stable populations, where the relationship between dentist and patient was more likely to be social as well as professional.

Much has changed since then, however, and even the most rustic communities nowadays tend to have had some exposure to computers; for example, in the guise of automated teller machines in banks. Therefore a computer in a dental practice is less likely to be treated with suspicion. A study in 1985 (Lamey) indicated that only 8% of patients experienced any anxiety about the use of computers in a dental surgery, and most of the fears arose from doubts as to who would have access to the information stored in the system. The survey stressed that the vast majority of patients felt that the presence of a computer in the surgery would not make it any more difficult for them to relate to the dentist. Most of the people who did express any concern about computers were elderly. It is no coincidence that a survey in the US (Kerr, Leahy and Bailit, 1985) indicated that older dentists are far less enthusiastic than more recent graduates about the use of computers in their surgeries. It may well be advisable not to computerise if the practice is mainly geared towards elderly

patients. However, the whole population is every day becoming more and more exposed to computers so the time will no doubt come when everybody accepts them and uses them just as they would a telephone or a calculating machine.

A far more serious concern is the acceptance of the machine by the staff who will actually be using it. In the chapter on systems analysis the importance of fully involving all the practice staff during the planning stage of computerisation was stressed. However there is always a temptation, particularly if only a small system performing one or two applications is purchased, to simply bring it into the practice one day, and expect the staff to accept it. To do this is to invite disaster. There is a strong possibility that staff will resent the new computer, thinking that their jobs may be threatened (although it is extremely unlikely that acquisition of a computer will allow a practice to reduce its staff unless it is overstaffed to begin with). Also, the acquisition of a computer may be seen as implying that there is something wrong with the present system, and this is likely to offend long-serving staff who, in their own opinion, have been doing the job perfectly well without a computer. Some may maintain that only they know how to do their job, and that their tasks cannot be computerised.

It is an unfortunate fact that human beings tend to fear things that they do not understand, and certainly computers fall into this category for most people. A new computer with its attendant new work practices and responsibilities can be quite frightening, and it is quite natural for people to resist change under these circumstances. Reactions vary; while most staff will persevere until familiarity with the computer removes their fears, there is a distinct possibility that disgruntled staff may, through their actions, ensure that the computer system does not work.

This may seem to be an unduly pessimistic attitude since, if the advice in Chapter 2 has been followed, steps will have been taken to optimise the efficiency of the practice prior to computerisation, which will of course mean that all unsatisfactory or inefficient staff will have been dismissed. No doubt the vast majority of practices today are well managed and organised, with high morale among the staff, who are all of high quality. But the few

practices which do, occasionally, have staff problems, should be aware of the havoc that can so easily be wreaked on the data stored in a computer system by anyone who has learnt the rudiments of the system's operation. It would be far easier for an employee who has just been sacked to wipe all the data stored on the hard disk and tear up the backup floppy disks as he storms out of the surgery for the last time than it would for him to destroy 10,000 record cards.

The staff should therefore be involved in the computerisation process from its beginning, ie during the planning phase: they should be convinced that the computer system will make their jobs more fulfilling and indeed more highly skilled. Explain to them that there will be a shift in responsibilities, and new challenges and opportunities to learn new skills. Make sure that they are aware that during the initial parallel running phase, they will have to work much harder than usual, but stress that this will only be temporary; once the system is running smoothly, their jobs should be much easier and more interesting, with much of the tedious work eliminated. Once this stage is reached, the extra time they have available can be used to give improved service to the patients, perhaps as dental health educators or dietary counsellors, and the staff should be offered training in these skills so that they will assume a higher job status.

A practice computer system will only function satisfactorily with the support of competent and, more importantly, trustworthy staff. If the practice does not have such staff, it should not consider computerisation. The risks are tremendous, and the entire fabric of the practice is at stake.

6 Computer System Security

GENERAL

As computers in dental practices become more commonplace, and have increasing amounts of data stored within them, the subject of computer security becomes ever more important. This is a large and complex field, which encompasses aspects of privacy, an area of increasing concern which has led to the passing of the Data Protection Act 1984. In this chapter, all aspects of security and privacy are discussed, commencing with definitions of these concepts:

Data security refers to the protection of data against accidental or intentional disclosure to unauthorised persons, or unauthorised modifications or destructions.

Privacy refers to the rights of individuals and organisations to determine for themselves when, how, and to what extent, information about them is to be transmitted to others.

Data in a computer system has to be protected from the following hazards:

Unintentional occurrences:

negligence

machine failure

fire, flood, etc

program errors

data transmission errors

user errors

Intentional occurrences:

vandalism

sabotage

curiosity

crime

The most basic precaution against loss of data is that of taking backup copies at regular intervals onto removable storage media, such as floppy disks. The system specification for computerisation of patient records released by the DHSS in 1986 requires software to work in such a way that practices cannot go for more than three days without taking backups. If data from the hard disk is not backed up by then, the system should refuse any further transactions other than a request for backup to be performed. This is a minimum requirement, and backups should in practice be taken at least daily. Two copies should preferably be made, and these should be stored in different places, both away from the hard disk, and as securely as possible, preferably locked in a fireproof, watertight safe. Also, care should be taken to replace floppy disks long before the end of their useful life. Always use good-quality disks bearing a reputable brand name; the small savings achieved through using unbranded disks are simply not worth the risks involved.

Electrical interference may be a problem in the dental surgery, and this may possibly corrupt stored files. Any such potential problems should be uncovered by thorough testing before significant amounts of data have been entered into the system.

PROTECTIVE TECHNIQUES

Three principal techniques can aid the protection of a computer system against intentional misuse:

1 The use of passwords to prevent unauthorised access to all or part of the system and its functions.

2 The encryption of stored data, to prevent it from being understood if accessed by unauthorised means

3 The provision of an audit trail (possibly by logging all system transactions) to maintain a record of exactly what has been done, and by whom.

The extent to which these techniques are used will depend on the nature of the data stored in the system, and also whether or not the system is acceptable remotely via the telephone line or other external connections. Consider first a simple single terminal system, unconnected to the outside world, but used for many important functions within the practice. It is probable that most of the time the computer will be operated by non-clinical staff. If any doubt exists as to the reliability of the staff, certain system functions such as deletion of files should be barred from them. In order to implement different access permissions for different users a password system must be installed.

Care should be taken in choosing passwords – too many people use obvious ones such as their first name or their car registration. This kind of sloppiness will in time lead to a breach of security. As well as using obscure combinations of letters and numbers, passwords should be changed regularly. Obviously, in any practice system with connections to the outside world via the telephone or other lines, a tightly controlled password system is absolutely essential. The extent of the threat posed by would-be 'hackers' to dental computer systems is not yet known, but no doubt when the electronic estimate transmission system is fully established, guidelines will have to be laid down on suitable password systems to be adopted.

It is unlikely that a practice computer system is to contain any sensitive data which the staff should not be allowed to read, so encryption of data is not an important issue here. However, provision of an audit trail is a useful feature. In order to implement an audit trail, it should not be possible for any user to change the date or time in the system. Therefore it should perform date checking on start-up, the correct date being supplied by a battery driven clock within the system unit. This requirement appears among the DHSS specifications. Every time an instruction is input to the computer, the system keeps a record of that transaction, which is 'stamped' with the date on which it took place. If each transaction in the computer is date stamped

(and preferably time stamped too), a record of all the transactions, in order of occurrence, can later be inspected by the practice owner on supplying the appropriate top-level password. This will not only allow him to see where a mistake was made earlier on, but will show exactly what the operator was doing, and when. Thus can staff activity be monitored very closely. If more than one member of the ancillary staff use the computer, they should all be given passwords and required to log on under their own passwords; this will help to identify anyone misusing the system.

PRIVACY AND CONFIDENTIALITY

The use of a computer renders patient data more secure from unauthorised access by those other than staff of the practice than does a conventional manual system, because anyone can pick up an FP25 and read the information on it, whereas a degree of familiarity with the computer is needed to access records from it. So the most obvious way of preserving confidentiality is to restrict physical access to the computer terminals, by ensuring that they are not overlooked by patients during the day, and by locking rooms containing the computer and its terminals when these rooms are not in use.

Password control will prevent an outsider actually logging on to the system while the member of staff has been temporarily called away, but if the computer is already logged on under the staff member's permission, an inquisitive patient could theoretically access data much faster using it than he could from the FP25s in the filing cabinet. Therefore no terminal should be left unattended while logged on; staff should log off before leaving their terminal.

Great care should be taken not to leave printouts lying around, as they might contain highly condensed or summarised information which could be very rapidly read and assimilated by an unauthorised person. Printers, being noisy, are often situated in a small room by themselves, remote from the surgery and reception, and there is always a temptation, having dumped out some vital information to the printer, to leave it and collect it later. Unless the printer room is kept locked, this temptation should be resisted.

Different levels of password can be implemented, giving varying degrees of access to stored data. For example, there will probably be no need for non-clinical staff to access patients' medical histories, so they can be barred from accessing that data. Similarly, access to sensitive information can be denied to certain terminals, no matter who happens to be logged on there. The 1986 DHSS Patient Record system specifications state that medical history information should not be accessible from terminals situated in a reception area.

THE DATA PROTECTION ACT 1984

The full title of this Act is: 'An Act to regulate the use of automatically processed information relating to individuals and the provision of services in respect of such information'. It protects the individual against potential misuse of personal information about him held on computer, such as unauthorised disclosure of data, or holding inaccurate data, and gives him the right of access to data of which he is the subject. It has considerable implications for dental practitioners who maintain computerised patient records.

Since May 1986, any dentist maintaining personal information of any sort in a computer system has been required to register as a data user with the Data Protection Registrar, and to comply with a series of data protection principles. On registration, he must describe in detail the type of data held, the purposes for which the data is held, the source of the data, and names of the persons or organisations to which he discloses the data. It is an offence for anyone to process personal data by computer without being registered, or to operate outside the terms of their register entry. Fines for failure to comply with the Act are unlimited.

The data protection principles specified by the Act state that personal data shall:

- be collected and processed fairly and lawfully;
- only be held for specified, lawful, registered purposes;
- only be used for registered purposes or disclosed to registered recipients;

be accurate and relevant to the purpose for which they are kept;

— be accurate and, where necessary, kept up to date;

— be held no longer than is necessary for the stated purpose;

– have appropriate security surrounding them.

These principles also embody the entitlement for individuals to have access to personal data held about themselves (subject access), and to have the data corrected or erased.

Dentists should assume that if they hold personal information of any sort on computer, they are subject to the Act and must register. Personal data held for the purpose of payroll, pensions, or accounts are exempt from the whole Act, but there are strict definitions of the purposes in each case. It is unlikely that this exemption from registration would apply to many dental practices so it is recommended that all users of computerised data be registered.

The Act gives patients the right to be compensated for damage or associated distress suffered as a result of any inaccurate data concerning them which is held on a computer, or as a result of the loss or unauthorised disclosure of such data. Therefore it is vital that all staff are made aware of the importance of absolute confidentiality and should be instructed that under no circumstances should information concerning a patient be disclosed to anyone except under the direction of that patient's dentist. Staff contracts of employment should have a confidentiality clause. Of course these recommendations apply equally to practices using only manual systems.

Data held must be, as far as possible, accurate and up-to-date. Much of the information obtained from patients is necessarily subjective. The record should therefore state clearly which information has been obtained from the patient, and which from a third party. Medical opinions should be clearly recognisable as such. Data should not be retained for longer than is necessary for the purpose for which it is held. BDA guidelines suggest that dental records should usually be kept for not less than six years in the case of adults, and for minors, until the age of 24. Records of

patients who have not attended the practice within six years should be reviewed to determine whether their retention is necessary.

From November 1987, the Act gives everybody the right of access to any information about them stored on a private computer system. Such information may only be withheld if its disclosure is likely to cause serious harm to the physical or mental health of the data subject or another person.

Records of the opinions of the dentist regarding the data subject come within the definition of 'personal data' required to be disclosed to the data subject. Therefore, the dentist should beware of entering derogatory comments in the records of his less favoured patients, no matter how accurate they may be! Information held on computer giving the intentions of the dentist in respect of an individual is outside the Act's definition of 'personal data', and so may be excluded from disclosure to data subjects.

Requests from patients for access to information stored about them on a dental practice computer must be made in writing, and should be responded to within 40 days of receipt of the request. The practice may charge a fee up to a maximum of £10.

The dentist responsible for the care of the patient concerned should decide how information should be disclosed, and whether any information should be withheld in the interests of the patient. It is of course important to verify the identity of the patient making the request prior to releasing any information. Written records of requests and disclosure of information should be maintained.

The 40-day period does not start until the dentist has received all the information necessary to firmly identify the data subject and obtained the consent of any third party to disclosure of information about them which may be contained in the record. Records need not be supplied in the form of a printout, and, if they are not intelligible without explanation, should be accompanied by an explanation of the terms used. It is advisable, when giving a copy of the record to the patient, to ensure that he understands it, and to allay any possible fears in his mind about

the contents. In addition, the confidence must be maintained of any other person mentioned in the records either as a source of information about the subject (other than health professionals involved in the care of the subject), or as another individual to whom the information or part of it relates, and so any reference to such a source or individual either by name or any other identifiable means must be removed prior to disclosure.

All individuals, including children, have the right of subject access. If a request is received from a child, a data user will need to judge whether the child understands the nature of the request. If the child does understand, the data user should reply to the child. A reply should be given to a request made on a child's behalf by a parent or guardian only if the data user is satisfied that the child has authorised the request. If the child does not understand, the parent or guardian is authorised to make the request on behalf of the child and to receive the reply.

Data subjects who are dissatisfied with the data held about them or with the response to their request for access to such data may appeal to the Data Protection Registrar and, if necessary, to a Data Protection Tribunal.

Registration packs are available from Post Offices. The registration fee is currently £22.00 per application, and it is recommended that, in a multiple practice, all the principals register, since they are each responsible for the records of their own patients. Registration entries are valid for three years, after which registration must be renewed.

Further advice on the Data Protection Act can be obtained from the BDA*, the Data Protection Registrar**, or The National Computing Centre.

*British Dental Association, 64, Wimpole St, London W1M 8AL.
**Data Protection Registrar, Springfield House, Water Lane, Wilmslow, Cheshire SK9 5AX.

7 Further Applications

We have so far considered only those applications of computers concerned with practice management. There are, however, a number of other ways in which computers can help in a dental practice, and this chapter will deal with some simple ideas that are already a practical proposition.

PATIENT EDUCATION

Many dentists, prior to purchasing a business computer for practice administration, have owned a small 'home computer' such as a Sinclair Spectrum, BBC microcomputer, Commodore 64, QL, or another of the many machines which were bought in their millions when the home micro craze swept the country in the early 1980s. They may well have relegated these to the attic having grown tired of playing games on them, but even small machines such as these can be put to excellent use in the dental practice. The idea is to use them to display a sequence of pages on a conventional domestic TV screen in the waiting room.

Since many practices have TVs in the waiting room anyway, it would seem a good idea to use them to get a message across to the captive audience, and the high resolution graphics and colour available on home computers renders them entirely suitable for creating eye-catching displays. These could contain advice on oral hygiene and diet, or perhaps information on the more advanced types of treatment on offer; this is a powerful way of increasing patient awareness and hence stimulating demand (Benn 1984).

In 1983, the General Dental Council, recognising the potential of the computer in patient education, sponsored a national

competition for schools, with a prize to be awarded to the best dental health program written to run on a home microcomputer. The winning program, *Teeth and Dental Care**, was of a very high standard, and met with considerable success, being widely distributed in schools, and adopted by several health authorities for use in their dental education programmes. However it was written for the BBC computer only, and it is a pity that the competition has not been instituted as a national event because it would doubtless stimulate considerable interest in dental health within the participating schools, and would yield further high-quality educational software, for a variety of small computers, for use in dental practices, without incurring any significant development costs.

Owners of other computers who wish to use them for waiting room displays will have to write their own software, but this is not a difficult task and indeed is a highly suitable project for the beginner wishing to teach himself some elementary programming! For those with an absolute aversion to programming, however, there are many specially-written packages which allow the user to create effective displays on most home microcomputers. Details of these can be obtained from suppliers. The program should be written to last around 15–20 minutes then repeat automatically; it can be left running all day without any attention, unlike the educational videos now becoming popular which not only require an expensive video recorder, but also need frequent rewinding!

If the computer is running a non-interactive educational program, it can of course be kept safely behind the reception desk, away from interference, connected to the TV set by a long lead. If, however, you are willing to let the patients have access to it, there are many educational programs requiring interaction from the user which are highly suitable for younger patients and this may well help them enjoy their visit a bit more. If you do not already have a home computer they can nowadays be bought very cheaply and there is a flourishing second-hand market – classified advertisements in local newspapers are a good place to look. A Spectrum can be had for well under £50 nowadays and even the more powerful QL can be found at a bargain price.

*Available from Garland Computing, 35, Dean Hill, Plymouth

Besides being useful for creating video displays, the graphics capabilities of home computers are ideal for creating educational literature for printing using a dot matrix printer. With the help of one of the many painting and drawing programs available for home computers, a practice logo can be designed, and used in conjunction with diagrams of toothbrushing or any other desired image, to create the practice's own dental health literature, thereby helping to show how much the practice cares about its patients.

BULLETIN BOARDS AND VIEWDATA

In Chapter 3 we saw how the use of a modem will allow the practice computer to connect with the DEB computer for the purpose of claims submission. There are other computers which the dentist may well find it worth dialling up, however.

A bulletin board is a means of storing information on a computer which can be read remotely using other computers, via the telephone line. A central computer (which need only be a small microcomputer) is attached to a telephone line via a modem, and runs software which enables it to interpret requests for information from distant computers, and to transmit the appropriate information via the telephone system to the terminal from which the request originated. The distant user can also leave messages on the bulletin board, which can be private, in which case they will only be readable by the bulletin board system operator (or sysop), or they may be open access, readable by anyone else dialling that bulletin board.

The General Dental Practitioners Association (GDPA) established a dental bulletin board in May 1986*. It contains regularly updated information on matters relating to computers in dentistry, and provides a forum for the exchange of views in which anyone with a computer and a modem can participate. A further use of the bulletin board is for the dissemination and sharing of telesoftware; programs relevant to dental practice can be submitted to the bulletin board, from which they can be downloaded by other dentists into their own practice computers. It is to be hoped that further dental bulletin boards will be set up as more and more practices have computers.

*Further information from GDPA Online, 4, Spring Walk, Whitstable, Kent CT5 2AY.

Telesoftware can be subject to a charge, usually by means of electronically debiting the account of a bulletin-board subscriber, or it may be supplied free of charge. Programs supplied free of charge (which need not be telesoftware, some are available on disk through mail order) are known as public domain software. The idea of distributing free programs is that the user has a chance to try out the program thoroughly. If he considers it to be of use to him, the program documentation gives details of a suggested contribution and the address to where it should be sent. If the user elects to pay this contribution (it is usually only a nominal amount), he becomes a registered user and will receive free upgrades when they are released, plus a limited amount of support service, either by telephone or mail. It is likely that a certain amount of dental software will be written for the public domain and this is certainly to be encouraged.

Bulletin boards are just one type of viewdata system. Viewdata is the generic name given to the technology which allows large numbers of users to access information in a paged format from a central computer onto their own terminals. British Telecom's viewdata system is called PRESTEL and this service, established in 1979, stores millions of pages of information in a network of large computers, which can be accessed by any subscriber using their own computer and a modem. Besides featuring all the latest news and 'magazine' pages, containing information similar to the television CEEFAX and ORACLE services, PRESTEL also acts as a gateway, allowing further connections to be made to other private computers connected to the system. This provides facilities such as teleordering and telebooking, by means of which goods can be ordered, or travel arrangements made, at any time of day or night, through dialogues with the computers of the companies concerned. Already at least one dental company offers the facility of teleordering.

The advantages of ordering dental supplies using viewdata, as opposed to simply placing a telephone order, may not be immediately apparent. But, besides allowing orders to be placed at any time of day, thus giving the opportunity to take advantage of off-peak telephone rates, a computer-based ordering facility can display up to date prices of all goods available, and details of any special offers or new products. It may not be long before

practices no longer need company representatives to call to take their orders.

Yet another viewdata facility of potential use to the dentist is the telebanking service, which allows cash transactions to be made electronically, without the need to visit the bank in person or to issue written cheques. Transaction requests can be made at any time of the day or night, instant on-screen statements of account are available, and charges for electronic transactions are lower than those for ordinary cheques. At present, this service is only offered by one bank, the Royal Bank of Scotland, but other major banks are known to be considering the introduction of this facility.

8 The Future

GENERAL

So far, mainly administrative functions of computers in dentistry have been dealt with, and no clinical uses have been mentioned. It is impossible to predict whether management and administrative benefits alone will provide a sufficient incentive for the vast majority of practices, as yet uncomputerised, to embrace the new technology. It should by now have become clear that there are many tradeoffs to be made when considering computerisation, and that not all practices have anything to gain from automating their administrative systems.

There are however many developments in dental computing which seem certain to change fundamentally the nature of clinical dentistry, and these are the subject of this chapter. It is quite likely that the long-awaited computer revolution in dental practice will be as a result of developments in clinical applications of computers, which will result in a non-computerised practice being regarded as lacking essential equipment, in the same way as we would now regard a practice having no X-ray machine.

Most of the clinical applications of computing which promise to affect our lives in the foreseeable future, ie within the next ten years, are concerned with its use in diagnosis and treatment planning, and this chapter will be confined to the discussion of this field. We will not be discussing any applications arising out of the fast developing science of robotics (to which computing is fundamental), enormous though the benefits may prove, especially in laboratory automation; let us keep speculation to the minimum by concentrating on areas where considerable advances have already been demonstrated.

It has always been considered a duty of the dentist to keep abreast of developments in his profession, and to maintain his knowledge and skills through continuing postgraduate education. However, the pressures of maintaining a practice, and the expense involved, have deterred many from attending postgraduate courses, with the result that overall levels of education have suffered. There are a number of trends in general dental practice which will put increasing pressure on dentists to bring their knowledge up-to-date, and to broaden their skills, but the enormous amount of current research, and the rapid rate of change in our knowledge, make the task of keeping up-to-date ever more difficult.

Furthermore, it has been suggested that the changing pattern of dental disease in this country, with the resulting reduction in the need for what is generally regarded as 'routine' treatment such as simple conservation and prophylaxis, will encourage dental practitioners to perform more complex forms of treatment, an obvious example being orthodontics. Because the orthodontic experience of general dental practitioners is usually limited to removable appliances, selection of appropriate cases is essential. However, if the dentist has had little recent experience of orthodontics, he may not have the knowledge needed for such a decision. This has led to an increase in the number of cases referred to orthodontic consultants for advice, and also an increase in their workload due to cases where treatment by a practitioner has been unsuccessful (Sims-Williams 1987). It would therefore be of considerable benefit if a computer could provide the dentist with the knowledge on which to base his decision on whether to treat or refer and, if a case was amenable to simple removable appliance therapy, to suggest a suitable treatment plan.

Even in the provision of more routine forms of treatment, it appears that dentists could benefit from computer-aided decision support. The 1986 report of the Schanschieff Committee on Unnecessary Dental Treatment affirmed that the ability of many dentists to diagnose dental caries and periodontal disease left much to be desired. As has been noted, the recommendations of Schanschieff have had considerable influence on the programme for increasing the monitoring activities of the DEB computer,

and it seems certain that members of the profession will come under increasing pressure to conform to recommended prescribing philosophies. There will be more uniformity in the way dentistry is practised, certainly as far as the NHS is concerned, with decisions regarding treatment arrived at on the basis of scientifically accepted rules, rather than the empirical observations of the individual. Suitably programmed computer systems will therefore prove invaluable in providing guidance.

Some aspects of diagnosis are always going to be difficult for the unaided human, however thorough his education may be; for example, the interpretation of dental radiographs. Interproximal caries can be very hard to detect from bitewings. Yet, as the public come to expect more from the dental service, errors in diagnosis become less acceptable. This would appear to be another area in which computers show promise.

To talk glibly of computers helping us in clinical decision-making is all very well, but there seems to be something of a credibility gap between using them as tools for what are, after all, mundane administrative tasks (such as filing, record keeping and accounting) which most of us would quite happily delegate to a 16 year old school leaver, and using them actually to help us in making clinical decisions – implying that they know more about our job than we do. We are in fact talking about a whole new breed of computer system altogether; one that has been described as belonging to the fifth generation, which will see the development of truly intelligent computers.

ARTIFICIAL INTELLIGENCE

We saw in Chapter 1 how computing technology had evolved, starting with simple devices such as the abacus, through the age of mechanical and electromechanical punched-card equipment, into today's complex electronic computers. Much emphasis was placed on how little their basic processing operations had changed along the way.

Since their initial development 40 years ago, computers have always been used in intelligent action, but there has never been any doubt as to where the intelligence came from; it came from the programmer. The programmer chose the goal, decided how

the goal was to be reached, and ensured that the user received prompts to input all the data necessary for the computation. The computer merely carried out the operations designated by its program. There was nothing unpredictable about its operation; given the same program and the same data, it would always arrive at the same results. It can therefore be argued that the computer can no more be described as 'thinking' (and therefore 'intelligent') than an ultrasonic scaler could be described as scaling. Just as the task of scaling is performed by a dentist or hygienist, using a scaler as a tool, it is the human who thinks and arrives at decisions, merely using the computer as a tool.

What about a scaling device, though, that could clean an entire dentition without any more human involvement than is needed in switching it on and placing it in a mouth? And what about a computer that plays chess so well that it can beat the human who wrote its program? The purpose of these rather hypothetical questions is to make the point that just as there has to be a point where the automatic scaler ceases to be a tool and actually becomes that which performs scaling, so we believe there must come a point where the computer ceases to be a tool and becomes that which thinks. And that point will presumably come when the human being ceases to have any active role in the operation or decision process.

Artificial intelligence (AI) is the name given to a part of computer science which is concerned with designing intelligent computer systems, ie systems which exhibit the characteristics we associate with intelligence in human behaviour, such as learning, reasoning, and solving problems. In other words, AI is concerned with programming computers to perform tasks that are done better by humans at the present time, because they involve such higher mental processes as perceptual learning, memory organisation, and judgmental reasoning. The discipline of AI is closely related to a wide range of other academic subject areas besides computer science: these include psychology, philosophy, linguistics, and engineering.

At the fundamental level, AI is about the simulation of human behaviour: the discovery of techniques that will allow us to design and program machines which will both emulate and extend our

mental capabilities. Useful though the present generation of dental computer systems are, they could hardly be said to fall into this category.

The idea of developing intelligent machines is certainly not a new one.* Almost as soon as electronic computers were invented, attempts were made to get them to think like human beings. As early as 1950, the great computer pioneer Alan Turing proposed a test which would determine whether or not a computer was capable of intelligent behaviour. The essence of the test was that an interrogation session would be set up, in which an interrogator asks questions of two entities, A and B, one of which is a person and the other a computer, neither of which he can see. The interrogator can specify which entity should answer which question, but he cannot expect the entity to tell the truth all the time, so it would be no good asking A 'Are you the computer?'. Under the terms of the Turing test, a computer is regarded as exhibiting true intelligence if the interrogator cannot tell which of A and B is the human, and which the computer.

While rapid progress was made with computerisation of conventional, 'non-intelligent' applications in the 1950s and 1960s, leading to an increasing commercial acceptance first by large, then by progressively smaller organisations, AI research was slow to bear fruit. Although special computer languages had been developed specially for building AI applications – the principal AI language, LISP, dates back to 1960 – the major difficulty was the very high processing demands made by AI applications. There simply was not, until recently, sufficiently powerful hardware available to put the ideas of AI researchers into practice.

Early AI research was largely directed towards the development of computer systems that could learn, gradually increasing their knowledge, in the same way that a human being begins life with no knowledge, but gradually learns, the level and scope of his knowledge increasing with age and experience. It was thought that if such a learning machine were developed, there would be no theoretical limit to the knowledge it could acquire, and thus it would become a sort of all-purpose sage.

*In fact it can be found in ancient mythologies

Unfortunately, this approach did not prove fruitful. The problem is that there is much more to intelligent reasoning than simply holding a vast number of facts in memory. Learning alone is not enough; what is needed is the ability to infer new facts from what is already known. So there has been a move towards the study of the structure of knowledge, with the aim of devising methods of representing knowledge which will allow further inferences to be made from that which exists. Since it is easier to create a working knowledge structure within a tightly defined sphere of expertise, than it is to give the computer even a modest degree of 'common sense', AI research has for the last 15 years been directed mainly towards providing computers with a body of knowledge in a certain area, and attempting to give them the ability to use that knowledge intelligently. The resulting computer systems are known as expert systems.

An expert system can be defined as:

"A computer program which uses knowledge and inference mechanisms to solve problems which, when tackled by humans, require significant expertise."

There are several important characteristics of expert systems which set them apart from traditional, conventional computer programs:

1 They can handle imprecise data. Conventional programs, when questioning a user interactively, require a definite yes/no response or selection of a definite choice from a number on offer. They do not work in terms of 'probably' or 'maybe'. But so many of the decisions we are faced with in real life are not clear cut; given two alternatives, we may be 30% in favour of one, and 70% in favour of the other. Expert systems allow us to express this type of information so that it can be taken account of by the system.

2 They can employ inexact knowledge. It is easy to embody rules such as 'If the sky is cloudy then there is a 60% chance of rain' within the expert system paradigm. This is much more difficult using conventional programming techniques.

3 They can exploit knowledge at the 'correct' time. Conventional programs work on a strictly sequential basis where the order in which individual instructions are executed is predetermined. This running order cannot be changed by the program itself in the light of new knowledge which it has just gained. Expert system programs, on the other hand, have no fixed running order; processing is driven entirely by the data that the program currently has available to it, rather than by any predetermined set of instructions. This is obviously more in tune with the way the human brain works; being able to react to events.

4 They can explain and justify their conclusions. If we want to set the computer tasks which we ourselves find difficult, we need to know how it reaches its conclusions. Furthermore, at any stage in the consultation, we need to know why it is asking the questions it does ask. The conclusions reached by a conventional program follow automatically from its instructions and the data provided to it; no explanation is necessary.

5 They can be changed and expanded relatively easily. We saw in Chapter 2 how important it is, when designing conventional programs, to determine in advance exactly what the requirements of the system will be, as it is very difficult to add to such systems without a total rewrite. Expert systems, on the other hand, can be changed or expanded easily to take account of changes in requirements, or additions to knowledge.

Because expert systems are so different from conventional programs, it is worth describing briefly how they are built, and how they work. The knowledge in an expert system is held in its knowledge base, in the form of simple rules, written in English text, or very nearly, on which it bases its decisions. A rule usually consists of a condition and an action to be taken when the condition is met; the action is usually to draw a conclusion or inference, which leads to further information being included within the knowledge base. It also has an interpreter, which cycles through the rules, testing them to see if their conditions are met.

A knowledge base may contain several hundred rules. The advantages of this method of structuring knowledge are that

qualitative and quantitative data can be used; the knowledge base can be easily inspected and incrementally updated by adding new rules; and also the knowledge is held in a form familiar to humans.

The steps in building a knowledge base are as follows:

1 A suitable expert, or team of experts, has to be found, and they must be willing and able to devote the necessary time to the project.
2 A person with knowledge both of computer systems and the area under study is chosen as the knowledge engineer – his job is to elicit from the team of experts exactly what they do, and how they do it.
3 An early prototype system is rapidly constructed, with just a few basic rules, and this is given to the experts for evaluation.
4 After testing the prototype and discovering the boundary of its knowledge, the experts then suggest further rules to extent its knowledge and improve its performance. These can be added to the original prototype to yield a better version; development therefore takes place incrementally.

Expert systems clearly have much to offer in all fields of clinical dentistry, and many are currently undergoing development. An important feature of expert systems is that they are always in a developmental stage; an ėxpert system can never be complete, any more than a human's knowledge of a field can ever be complete; there is always more for it to learn. But unlike humans, expert systems never forget what they know, so it is reasonable to expect that an expert system will become gradually more and more useful with the passage of time.

COMPUTER-AIDED DIAGNOSIS

There is a strong link to be made between the administrative uses of computers and their application in clinical diagnosis. When comprehensive clinical information is maintained online, data thus stored can be manipulated by the computer, yielding information on the longevity of different types of restoration, the

success rate of different treatment regimes, and other epidemiological data. Comparison of the results from the patients of a number of dentists can give an insight into the correctness of their diagnostic methods and the effectiveness of their clinical procedures.

One of the earliest uses of computers in dentistry was to assist in distinguishing white lesions of the oral mucosa (Kramer 1971). In this study, a computer was given detailed information concerning the histological findings in a series of cases where there was some difficulty in distinguishing between lichen planus and leukoplakia. The diagnoses made by the computer were sometimes in conflict with those made by the oral pathologists, and in these cases, it was stated that further investigations often vindicated the computer's diagnosis.

More recently, expert systems have been developed to assist in endodontic diagnosis (Hyman and Doblecki, 1983). It may sometimes be difficult to make the differential diagnosis of pulpal disease because of conflicting or insufficient signs, or because of limited experience. In such cases, an expert second opinion is invaluable, yet not many practitioners have easy access to endodontic specialists. In about 85% of cases, the computer system achieved results comparable to those of an experienced endodontist.

Ralls et al (1986) described a comprehensive computer-assisted dental diagnostic system, capable of diagnosing most dental emergency conditions, for use by physicians or other health care professionals in isolated environments not having access to a dentist. The program ran on a small microcomputer system, and initial testing suggested an accuracy rate of 95%. Such a system could be very useful in assisting newly qualified dentists to gain confidence in clinical decision-making.

The elicitation of a thorough history is of course a prerequisite to accurate diagnosis. The manner in which questions are presented by the dentist exerts a strong influence on the history obtained, and important information may not be recorded. Computer programs are being developed to aid history taking in a number of specialities, by presenting a series of questions to which the patient has to respond interactively. Such a program

contains questions based on a large number of symptoms and diseases. It follows the pattern of the patient's complaint by means of a logical hierarchical structure.

Each time a question is displayed on the screen, the patient has to respond, either Y for yes, N for no, or by making a selection from a number of options on a menu. The computer program then generates the next question from its knowledge of what logically follows from the responses given so far by the patient. The program leads eventually to a conclusion as to the most likely cause or causes of the patient's complaint. There are several important advantages of automated interactive history taking, which are as follows:

1 The knowledge of many experts in the field can be combined in designing the questionnaire.
2 The reasoning which leads to the next question is objective and reproducible for every case.
3 The patient has the opportunity to think carefully before responding.
4 Responses by the patient will not be influenced by any feelings he may have towards an individual clinician.

A diagnostic computer program offers the advantage of basing its evaluations on the accumulated evidence of many experts, who between them have seen more cases than the user could hope to see in a lifetime of practice.

ORTHODONTIC DIAGNOSIS AND TREATMENT PLANNING

The most valuable contribution of the computer in orthodontics is to the forecast of future craniofacial growth patterns from computer analysis of serial cephalograms (Sloan 1980). Cephalometric analysis can be assisted by the automatic calculation of distances and angles by computer. Results in current systems are displayed as tables of figures, or graphs, but in future, three-dimensional computer graphics techniques will allow simulation of future hard and soft tissue profiles on the screen.

DIAGNOSTIC MEASUREMENTS

Computerised clinical measuring devices which are already available, and which will no doubt become more accurate and more clinically useful, include endodontic apex locators, electronic pocket depth probes, devices used in gnathology to register jaw movements and detect TMJ abnormalities, and devices used to measure tooth mobility.

RADIOGRAPHIC ANALYSIS

It is accepted that radiological examination should be regularly carried out on dental patients, for the early detection of caries and changes in periodontal bone levels, as well as many other pathological conditions. The current visual method of interpreting radiographs has many disadvantages, due to shortcomings in the human visual system. Small changes in image density are very difficult to detect and it is often not possible to see tiny irregularities in the depicted bone structures because of the complex background of unchanged bone.

A considerable improvement can be obtained by means of digitised image processing techniques (van der Stelt 1985). These techniques are performed on a digitised image, obtained from the conventional radiograph. Each point of the original image is scanned, and is allocated a number according to the intensity level at that point These numbers are stored in the computer and are labelled with the coordinates of the points to which they refer. Each of these points are called pixels ('picture elements').

The number of grey levels, or degrees of intensity, can be 64, 128, or even 256 obviously the more grey levels, the finer differences in intensity will it be possible to detect. Similarly, the number of pixels used to represent the image can be 128 × 128, 256 × 256, or 512 × 512, or even greater; the more pixels used, the more accurate representation of the original radiograph will be achieved, but more memory space and processing power will be needed to render the image.

Conversion from the original radiograph to a digitised image is achieved by a TV camera interfaced with an analogue-to-digital converter, and the digitised image is held in a frame buffer – a special area of the computer's RAM dedicated to storing and manipulating images. Once the original image is represented by a matrix of numbers stored in the frame buffer, it is possible to

carry out any required processing of the digitised image. A large number of operations can be achieved by such processing; they include contrast enhancement, grey level normalisation, contour detection, noise (or interference) reduction, and other image enhancement procedures. Other operations aim at the detection of defects or significant structures in bone and teeth.

A further computer-aided technique is the subtraction of one image from another. Two radiographs are taken with an intervening time lapse, in order to reveal the natural progress of a lesion, or the effect of treatment. The two radiographs must of course have identical projection geometry. Subtraction of one image from the other will erase all unchanged structures, allowing the lesion to be detected easily.

Computerised radiographic techniques also offer the possibility for reduction in the amounts of radiation emitted in dental radiography. Low dose radiographic techniques generally yield a lower quality, 'noisier' image. However, noise can be reduced by digitised image processing, thus allowing satisfactory radiographic images to be obtained with less radiation.

Systems are being developed to display one or more radiographs as a three-dimensional image. 3D images may be real, constructed from a number of image 'slices' through internal structures, as in the CAT (Computerised Axial Tomogram) scanner, or may be artificial, obtained by adding shade to the original image, thus giving the impression of perspective. Both methods can be helpful in planning surgical and orthodontic treatment, where 3D information plays an important role.

TOOTH CHARTING AND CASE PRESENTATION

If a practice computer system is used to record and store clinical details, it should provide some means of graphically representing the dentition and any restorations already present or prescribed, as provided on the NHS FP25 and FP17 forms. The ability to record periodontal depths would be of great benefit, as would some improvement on the diagrammatic occlusally-viewed chart with which users of the NHS forms are familiar.

On a conventional chart, with the 32 teeth represented as two

straight rows of boxes of equal size, it is difficult to elegantly represent rotation, tilting, or impaction of teeth, or space closure. Efforts to show anything other than which teeth are present and which restorations have been done or are prescribed, tend to result in a confused, unintelligible chart.

A computerised chart should allow an accurate representation of the teeth as they appear in the mouth, with any angulations or rotations. With the advent of today's powerful computers, the provision of such high-resolution graphics facilities has become a practical possibility (McCormack 1985).

At the tooth charting stage, a full set of 32 anatomically shaped teeth are first displayed on the screen in a standard arch format. The clinician uses a mouse or tracking device to move a pointer across the screen to mark any tooth for which details are to be recorded. Once the appropriate tooth has been selected, details of restorations are input via the keyboard, using an abbreviated code. An 'erase' function is used to delete missing units, which is preferable to simply crossing them out as on a conventional paper chart. 'Move' commands allow the individual teeth to be tilted, rotated, or repositioned according to the movement of the mouse.

If the screen image becomes overcrowded with detail in a complicated case, computer graphics systems allow the user to 'zoom in' to a particular area of interest, and to highlight selected features; the resulting display can then be printed out to yield a hard copy. The new high-quality laser printers are ideal for this purpose.

Hard copy printouts of a graphic representation of a patient's dentition can be used to show him his dental status and to illustrate various alternative treatment plans. Such material is also useful for presenting cases to other colleagues for advice or consultation. The various treatment alternatives can be shown superimposed on the present state, to give a very lifelike representation of the predicted outcome.

A number of different views of the dentition can be stored, and the recording of a detail to one view of a tooth will automatically update all the other views. Although only two dimensional charting

systems have so far been developed, there is much interest in the building of three-dimensional graphics systems capable of representing the dentition. Three-dimensional graphics, however, require very powerful hardware in order to be viable, so it will be some time before such systems are available on a commercial basis.

Periodontal charting systems have been demonstrated which record bone depths graphically. This information is usually drawn onto a special chart giving both buccal and lingual full arch views. A special electronic pocket probe is used to measure depths at various sites and this provides the input to the system. Such systems are still experimental but are likely to be commercially available within the next decade.

ALTERNATIVE INPUT METHODS

Reference has been made to the obstacles to the general acceptance of computers caused by the shortcomings of current man-machine interfaces. The difficulty of communicating with the machine via a keyboard is one of the principal reasons for the reluctance of many people to become involved with computers, and cursor control or pointer mechanisms such as the mouse, while offering considerably easier input of system control data, such as instructions to select options from a menu, or to change screens, have little potential as regards the input of masses of subject data, such as patients' registration or clinical details. There are a number of developments which may in the future become available to assist data input in the dental practice.

Optical scanning

It is nowadays accepted that the 'paperless office' will never be achieved There will always be a need to deal with incoming data written or printed on pieces of paper, such as letters from patients, the FPC, or the DEB, accounts and invoices, laboratory slips the list is endless. If such data could be automatically read into the computer system, much typing effort might be saved.

Optical character recognition, in which individual characters are 'read' one at a time and converted into their ASCII code for use by the computer, have been in use in banks for many years, to read the bank sort code and account numbers printed on cheques.

However, recognition of letters, which of course come in different font sizes and styles, is considerably more difficult, and although low-cost OCR readers have been marketed, they proved unreliable and were soon withdrawn from sale. However, technical improvements may soon make this a viable low-cost form of data input.

Handwriting input

This has considerable potential as an alternative to the keyboard, since no special operator skills are needed, apart from modifying one's handwriting to a reasonably legible standard, if necessary. One technique uses a touch-sensitive pad divided into a grid. Text is entered by using a pencil or pen which has the additional advantage of automatically providing a hard copy. Various templates can be set up, such as patient registration details, medical history, etc, and the fields set up can be entered in any order. However, such systems are not as yet able to cope with joined-up handwriting, so the user is restricted to writing in upper case which is a relatively slow process compared to normal handwriting.

A variation on the touch sensitive pad is the touch screen, in which the VDU screen itself has a grid overlying it, the intersections of the grid being interrupted by a finger tip to signify a certain location on the screen. This is widely used in many commercial environments but is really only useful for command entry, and hygiene considerations would necessitate very frequent cleaning if used in the surgery.

Voice recognition

Speech is the most effective method of communication between individuals, and enormous effort is being directed towards the development of computer systems that can interpret spoken commands. Primitive systems are already available, but they only work with a limited vocabulary, and require each user to 'train' the system to recognise his or her particular voice. Since there is some degree of error in recognition using current methods, the various commands usually have to be spoken up to three times to teach them to the system; minor variations are then registered and subsequent recognition is good, though not perfect.

The great advantage of a voice recognition system is that it can be used for input within the surgery. The dentist relates his findings directly to the computer without having to turn his attention from the patient, as is necessary with keyboard or mouse input, and there is no risk of cross-infection.

COMMUNICATIONS

Besides communicating, via a modem, with the DEB computer at Eastbourne, as described in Chapter 3, and with other computers for the purpose of teleordering, telebooking, and telebanking, as described in Chapter 6, the dental practice computer system of the future will play a vital role in keeping the dentist in touch with developments in his field.

In the USA, dentists already have their own online information service, the American Dental Network (ADN), established in cooperation with the American Dental Association (ADA), and specifically designed to meet the needs of their profession (Castaldo 1986). Accessible from any practice computer via the telephone line, it offers access to a large number of databases useful to dentists. In addition, the network provides a variety of electronic business and leisure services. ADN services fall into four distinct categories:

1 Dental Information Services – ADA press releases; news of interest to the dental community; updates on matters of legislation relating to dentistry; listings and descriptions of postgraduate meetings; education courses and seminars, with the facility for directly registering for courses online; abstracts from dental journals.

2 Health Care Information Services – ADN gives access to the very large MEDLINE database, which includes all references contained in the Index to Dental Literature, and is the most comprehensive database of the published dental literature. Access is via a user-friendly, menu-driven program. Also, an online letter on drugs and therapeutics is updated every two weeks, and gives details of new drugs, adverse reactions, and drug interactions.

3 Business, News and Leisure Services – includes access to a general business database which contains material related to dental practice management.

4 Electronic Messaging and Bulletin Board Services – government bulletin boards in the US include material from the National Library of Medicine, the National Institute of Dental Research, and the Center for Disease Control, which provides up-to-date information on the AIDS virus. Private bulletin boards can be created for any dental society or user group. Online product ordering is of course also available.

If the current trial of electronic submission of estimates proves successful, it will not be long before large numbers of dental practices in the United Kingdom have their own computer and modem. Our own dental information network, along the lines of the ADN, will then surely become a viable proposition, and this will encourage the creation of new databases to meet the future information needs of dentistry in this country.

Appendix 1

Glossary

Access	To locate required data.
Access Time	The elapsed time between the instant when a program instruction is executed calling for data to be accessed from a storage device and the instant when the required data is delivered to the processor.
Address	An identifying label (usually a number) which designates a particular location in storage.
Alphanumeric	Pertaining to a character set which includes letters (A to Z), digits (0 to 9), and, usually, other special punctuation characters.
Analogue	The representation of numeric quantities by physical means.
Application Program	Software designed for a specific purpose, such as word processing, accounting, etc.
Architecture	The organisation and interconnection of computer system components.
Artificial Intelligence (AI)	A branch of computer science concerned with using computers to solve problems that appear to require human imagination or intelligence.

ASCII (American Standard Code for Information Interchange) The standard code used to represent alphanumeric characters in a form intelligible to computer systems.

Assembler A computer program that takes as input code written in assembly language, converting it into the machine language that the processor can understand.

Assembly Language A means of specifying instructions to a computer at a low level. This language lies between high-level languages, such as Basic and Cobol, and machine language, consisting of 0s and 1s.

Asynchronous Referring to a communications protocol which relies on 'start' and 'stop' bits to synchronise the originator and receiver of data.

Background Processing The automatic execution of low priority tasks, such as recall letter printing, during periods when the processor is not coping with higher priority, foreground tasks such as appointment booking.

Backup Duplicates of software or hardware components, used in the event of the original being lost, damaged, or malfunctioning.

Basic (Beginners All-Purpose Symbolic Instruction Code) A high-level programming language frequently used in microcomputer systems.

Batch Processing A technique in which a number of similar items or transactions to be processed, for example a batch of recall letters, are grouped and processed in a designated sequence during a machine run.

Baud A unit for measuring the speed of data transmission.

Binary A number system using base 2, in which only the digits 0 and 1 are used.

Bit Abbreviation for binary digit. The smallest unit of storage, which can take the value either 0 or 1.

Bug An error in the code of a computer program, which causes incorrect or unexpected output.

Bulletin Board A database containing information of interest to a specific group of people, who gain access to it from their own remote terminals via the telephone line.

Byte A group of adjacent bits which are operated on as a single unit, or word, by the processor. The number of bits to a byte depends on the processor. Most current processors work with a 16-bit byte.

CPU (Central Processing Unit) The full name for the processor, that component of the computer system with the circuitry to control the interpretation and execution of instructions.

Chip A thin wafer of silicon on which integrated electronic components are arranged to form a microprocessor.

Cobol (Common Business Oriented Language) A high-level programming

language developed for business data processing applications.

Compiler A computer program which takes as input a source program written in a high-level language, and produces as output an object program in machine language.

Data Plural of datum, which is an individual fact; the raw material which becomes information when it is communicated.

Database An integrated collection of various files required for a related group of applications, which provides an environment for the sharing of data.

Data Processing One or more operations performed on data to achieve a desired objective.

Dedicated Used to describe a computer or system devoted solely to performing a particular task or set of tasks, and incapable of doing anything else.

Digital Refers to information represented in numeric form.

Direct Access The ability to select a given record from storage without reading preceding records.

Disk A revolving platter on which data and programs can be stored.

Downtime The period of time during which a computer system is out of action, due to a malfunction.

Field A group of related characters treated as a minimum meaningful unit of information.

File A collection of related records stored as a unit.

Floppy Disk A low cost, removable, magnetic secondary storage medium.

Flowchart A diagrammatic representation of a procedure, function, or program, which shows the logic and sequence of specific operations.

Hardware The physical components of a computer system, including peripherals.

Integrated Referring to programs which are designed to be compatible with each other, and can share data between them.

Input Data which is to be presented to the CPU for processing.

Interactive System One that permits direct communication and dialogue between the user and the operating system that the computer is currently running.

Interface A shared boundary; for instance, the boundary between two systems, or between the user and an input or output device.

KB (Kilobyte) An abbreviation for a value equivalent to 2 to the power 10, or 1024 bytes: in other words, roughly a thousand bytes.

Language A set of rules and conventions used to convey information.

Machine Language A language consisting of 0s and 1s, that is used by the CPU.

Mainframe The largest category of computer, used in large organisations with vast processing requirements.

MB (Megabyte) An abbreviation for a value equivalent to 1024 KB or 1,048,576 bytes.

Memory Part of the CPU used to store data and programs while they are needed for processing.

Microcomputer In terms of physical size and cost, the smallest category of computer. Modern microcomputers are so powerful that the prefix 'micro' seems to have lost much of its relevance.

Minicomputer Intermediate between the microcomputer and the mainframe. The distinction between micros and minis has become somewhat blurred.

Modem (Modulator/Demodulator) A device which converts digital signals to analogue for transmission along a voice grade telephone network, and vice versa.

Mouse A device used to control movement of a cursor or pointer across a screen: an alternative to the keyboard for input.

Network An interconnection of computers and peripheral devices at dispersed locations to allow them to exchange data with each other.

Object Code A fully compiled or assembled program ready to be run by the computer.

OCR (Optical Character Recognition) The differentiation of printed characters through the use of light sensitive optical machines.

Online A term describing devices which are in direct communication with the CPU.

Operand The data unit that is operated on by a given instruction.

Operating System A suite of programs which control the overall operation of the computer, and which is available to the computer at all times during operation.

Output Information produced as a result of processing activity.

PAD (Packet Assembler/Disassembler) Used to convert data transmitted to it via a voice grade telephone line into a form suitable for onward transmission along a high-speed digital network, or vice versa.

Peripherals The input/output devices and auxiliary storage devices of a computer system, connected to the CPU by cables.

Pointer A data item in one record that contains the location address of another logically-related record.

Printer A device used to produce humanly-readable hard copy computer output.

Processor Abbreviation for central processing unit or CPU.

Program A sequence of instructions written to cause a computer to perform a specified operation or operations.

Programming Language A symbolic language in which a programmer codes a program.

PSS (Packet SwitchStream) A network of high-speed data transmission lines, owned by British Telecom.

RAM (Random Access Memory) Volatile memory inside the main computer unit, used for temporary storage of programs and data necessary for the current processing activity.

Real Time Descriptive of online computer processing of data for immediate use in controlling activities at the data source; a classic example is appointment booking.

ROM (Read Only Memory) A section of main memory from which data can only be accessed, not written to.

Software A set of programs and data associated with the operation of a computer system.

Source Program One that is prepared using a high-level language.

Spreadsheet A type of application program used to perform calculations on entire rows and columns of figures.

Storage Descriptive of a device or medium that can accept data, hold it, and deliver it on demand at a later time.

Systems Analysis A detailed step-by-step investigation of related functions and procedures to define what is done and ascertain the best way of doing it.

Terminal A device that performs input and output operations in a computer system. Usually consists of a keyboard and VDU.

Turnkey A term applied to a computer system which is supplied as a complete unit,

ready to operate; hardware and software purchased together.

VDU (Visual Display Unit) A screen-based device capable of displaying keyed input and CPU output.

Volatile Storage A storage medium that loses its con tents when the power supply is switched off or interrupted.

Winchester A term sometimes used to describe a hard (fixed) storage disk.

Word Synonymous with byte.

Word Processing The use of computers to create, view, edit, store, retrieve, and print text material.

Appendix 2

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